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HISTORICAL RESEARCH REPORT

Research Report TM/88/03
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Ergonomic guidelines for control room software used with automated vertical guidance of shearers. Final report on CEC Contract 7249/11/007

Talbot CF, Collier SG, Graveling RA

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FINAL REPORT ON CEC
CONTRACT 7249/11/007

ERGONOMIC GUIDELINES FOR CONTROL ROOM SOFTWARE USED WITH AUTOMATED VERTICAL GUIDANCE OF SHEARERS

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S.G. Collier
R.A. Graveling

January, 1988

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This report is made primarily from the point of view of ergonomics. The authors are not in a position to be able to take full account of non-ergonomic requirements and it may not, therefore, be practicable to fully implement ergonomic requirements.

Report on TM/88/03
CEC Contract 7249/11/007

INSTITUTE OF OCCUPATIONAL MEDICINE

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FINAL REPORT ON CEC RESEARCH CONTRACT 7249/11/007

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SUMMARY

Technological changes have brought about a considerable growth in automated systems in coal mining. Amongst these has been the advent of the auto-steering (vertical guidance) of shearers. Such systems have improved working conditions on the face for both men and machinery resulting in greater safety and improved efficiency.

As an adjunct to this, known in its production version as MIDAS (Machine Information Display and Automation System), a surface monitoring function has been developed which extends the information display element to the surface. The MIDAS system continuously transmits steering data and information from other sensors to the surface permitting the remote monitoring of the status and progress of the machine on the coal face.

The human element of any man-machine system is capable of responding to a wide variety of demands. However, this adaptability frequently masks the ergonomic inadequacies of technically-sufficient systems. To ensure the efficient and effective operation of a man-machine system such as that formed by the MIDAS surface information displays and their intended users it is necessary to pay attention to a wide range of ergonomics issues. This project was concerned with providing ergonomic guidelines for the design of software for this surface monitoring facility. In particular, it addressed factors such as the interactive dialogue and the design of the displays used by the system.

Following an examination of the existing MIDAS surface display system to determine those elements of software design which were relevant to the system and its planned development, the literature on ergonomic factors associated with computer systems was surveyed in order to derive general guidelines. These were formulated to assist in and encourage the use of ergonomic principles in the design and development of computer-based information systems.

These guidelines provided general aid in shaping the software systems and a number of issues raised by them were successfully implemented in software revisions. However, the guidance provided was at a level where it could be applied to many different software systems virtually independently of the planned users of any such system. In order to tailor the needs of the system more effectively, it was necessary to determine the specific needs of the users. This was achieved through a series of structured interviews with a variety of HQ, Area and Colliery staff. The survey identified a number of principle tasks for which the MIDAS system was used in a consistent manner, including monitoring current shearer performance and face management. However, there was a much less consistent utilisation of the system for other tasks such as fault diagnosis and engineering monitoring.

This information was then used in conjunction with the design guidelines to identify problems and to produce specific ergonomic recommendations for their solution.

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1. INTRODUCTION

Progress of a longwall face must be controlled accurately. If the face line is not kept straight and at the correct angle, both in advance and to the gate roads at either end, difficulties will arise in the alignment of face supports and also for coal clearance systems. One of the key elements in controlling face progress is in the steering of the coal cutting machine. The type of coal cutting machine most frequently-used by British Coal is a ranging drum shearer. Steering of a ranging drum shearer is achieved by ranging the machine boom on a fixed underframe. The operator must determine the optimum position of the boom in order to leave the correct thickness of roof coal, often without the aid of any visible marker bands in the coal seam. At the same time he must take into consideration the angle of the machine relative to face advance, and also remember that excessive steps in the roof can cause problems when advancing powered roof supports. If the cutting drum is allowed to stray too far upwards then the quality of coal can be spoilt by rock being cut. Conversely not cutting close enough to the roof or the floor means lost production and hence reduced efficiency. Steering is also made more complex by seam irregularities such as variations in thickness and geological faults.

Technological changes in the early 1980s have encouraged the exploitation of automation systems on underground mobile plant within British Coal. One of the major areas of development in this move towards automated systems has been in the vertical guidance of shearers. The Headquarters Technical Department (HQTD) of British Coal has been working on the automatic guidance of coal-winning machines for a number

of years. Shearers guided by such systems have been shown to cut coal more efficiently and with less waste than shearers steered manually. Roof control is improved and the coal cut is cleaner. In addition to improved productivity, better roof control also enhances safety and helps improve working conditions on the coal face. Hunter (1983) describes some of the monetary and other benefits. At one pit trial, the system cut a coal panel in 70% of the usual time. Materials costs were 25% lower and face delays were significantly reduced. Hence, great emphasis is being placed on the rapid exploitation of this development. Experience has shown that the successful exploitation is very much dependent on surface-based monitoring of the health and performance of such systems. This is particularly true during installation, commissioning and the trouble-shooting of systems failures.

In close liaison with machine manufacturers, British Coal HQTD have developed a production vertical guidance and machine condition monitoring system known as 'MIDAS' (Machine Information Display and Automation System). In addition to its machine control function the MIDAS system also continuously transmits steering data and information from other sensors to the surface. A computer system using this information can then be used to assess the performance of the automatic steering, to indicate the condition of the machine and to provide data regarding the status and progress of the machine on the coal face.

Software for the surface monitoring of this information is currently being developed and is based on a configurable supervisory monitoring system known as "SUMMIT" (Supervisory Machine Monitoring and Information Terminal). Current development work will allow SUMMIT to interface to any transmission system conforming to the draft communications standards of British Coal. Hence it can potentially be used for the surface monitoring of:

Vertical and horizontal guidance systems for shearers.
Coal heading machines such as the In-seam Miner (ISM).
Roadheader and circular tunnelling systems.
Coal face alignment systems.

The surface software used with MIDAS is an implementation of SUMMIT configured to match the mining method and machine type at each installation. Further software is then added to meet requirements specific to MIDAS and the monitoring of the automated shearer.

The fundamental objective of a computer information system is to act as a decision support aid. Ideally, such an aid should provide the user with all of the information necessary to make the required decisions. The operation of such a system and the interpretation of the displayed data should be as simple or natural as possible to the user so as not to interfere with the decision-making task. In most industrial or commercial situations it is impractical to fully achieve such ideal objectives. The economics of the situation usually demand that such systems are used by a wide range of users and aid in a wide range of decision-making tasks which may have conflicting 'ideal' requirements. However, careful consideration of the human factors involved in both the operation of such systems and the associated decision-making tasks can greatly enhance their usability and utility and hence the overall benefits to be gained.

The primary aim of this project was to produce ergonomic guidelines and specific software design solutions for implementation within information systems for the surface monitoring and control of automated shearer vertical guidance systems. In order to maximize the potential value of the project, the MIDAS surface software system was treated as a case study to provide results and techniques that were applicable across the whole range of possible SUMMIT-based information systems.

1.1 Ergonomic Design Philosophy and Principles

With the introduction of computer-based monitoring and control systems there has evolved an increasing awareness of the need to consider a wide range of ergonomic issues. Factors associated with the classic man-machine system diagram (Figure 1) such as the legibility of displays and the physical dimensions of controls still have a major role to play in the design, selection and layout of appropriate system hardware.

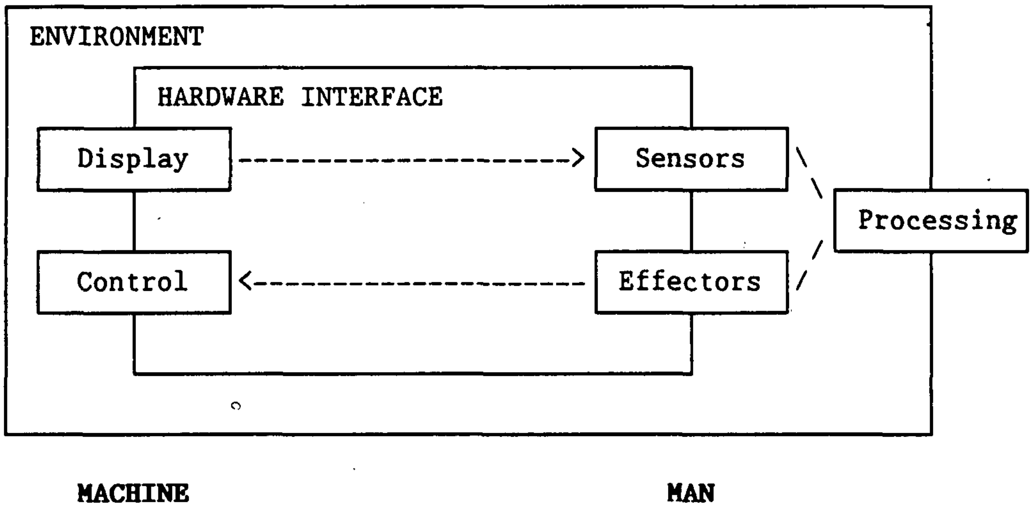

FIGURE 1. Man-machine System Diagram

However, this diagram does not encompass all of the factors which will effect the quality and efficency of operator decision-making and hence the overall reliablity of the system. An expanded diagram originally proposed by Simpson and Mason (1984) and further discussed in Best et al (1985) illustrates the much wider range of issues involved (see Figure 2). The expanded diagram shows a schematic representation of the man-machine system surrounded by five "shells of influence". These shells represent the generic areas into which the specific factors that can reduce reliable performance may fall.

The human element of the man-machine system is capable of responding to a wide variety of data display formats presented via a range of different media. However, this adaptability frequently masks the ergonomic inadequacies of technically sufficient systems. To ensure the efficient and effective operation of a man-machine system such as described by Figure 2, it is necessary to pay attention to ergonomic issues in all the areas described. Factors within the personal and organisational levels relate more to the implementation of completed systems and, although important, are to a large extent outside the intended scope of this project. Such issues are normally best dealt with at the "green field site" stage of system development. For

example, questions related to user expectations and concerns should be addressed by the effective use of training and the dissemination of information prior to system implementation.

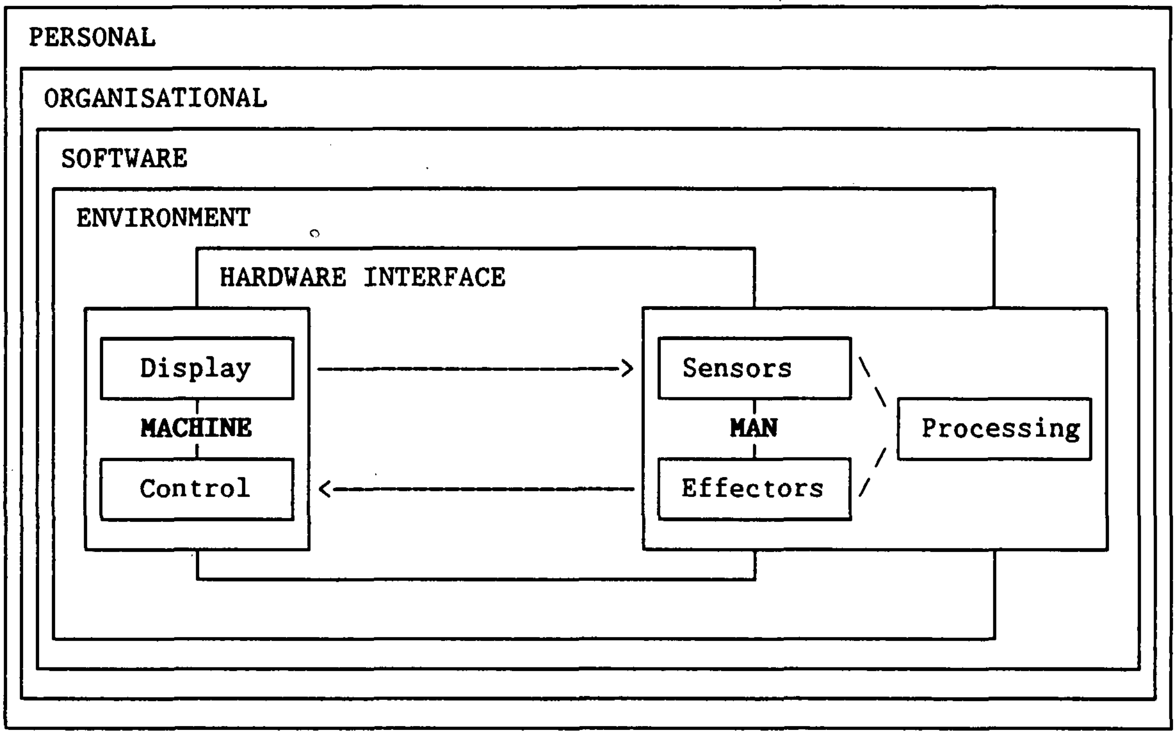

FIGURE 2. Man-machine System Diagram

This leaves the following, more immediate, issues:

(a) The environment the user is working in,
(b) The hardware the user is to interact with,
(c) The way the user communicates with the system (dialogue),
(d) The information required by the user.

The areas covering basic hardware design and the physical environment in relation to computer-based monitoring and control systems have been extensively discussed. Design guidelines are widely available both generally (see, for example, Cakir et al (1979) and Grandjean and Vigliani (1980)) and specifically in the mining industry (Simpson et al, 1982 and Mason et al, 1983).

In addition to the direct constraints covered by these guidelines, the physical environment within which the user is working also comes within the scope of the software design process. Factors such as heat, light, noise and workspace layout may well influence the willingness or even the ability of the user to perform the task required. For example, where adverse environmental factors are known to exist and are unavoidable the user interface needs to be designed with this in mind. The use of a keyboard bell signal to flag a warning or alarm message may be perfectly acceptable in an office environment, but it would be of little use in a high background noise environment such as a coal preparation plant.

Similarly, the hardware configuration of a system can have a large effect on the way in which a user interacts with a system. However, the hardware to be used is often predetermined by other system considerations that are to a large extent outside the scope of this document.

Most of the issues addressed by the project are therefore concerned with software factors such as dialogue and display design although, as stated above, there are obviously some areas of overlap and interaction at both the workspace layout and organisational levels.

The type and style of dialogue between a user and a computer system have a large effect on the user's attitude towards it. This in turn affects the efficiency of the total system. The type and style of dialogue best suited to a given application is determined mainly by the user's experience and expectations. If a user is inexperienced and does not know quite what to expect from a computer system, a great deal of time and effort may be needed to cope with an inappropriate interface. Conversely, an experienced user may feel frustrated and held back if expected to use a dialogue designed for a less experienced group of users. Consequently, it is important to consider the expected frequency of use and the range of experience of the target user groups. If the dialogue causes excessive difficulty or frustration for a user group, then they may feel the effort required to use the system outweighs its

usefulness or the additional effort involved can interfere with the quality of the actual tasks to be performed.

The range of data available on a computer information system is usually far in excess of that required by a user to perform a given task. The information required for a given task may be spread across many displays and in differing formats. From the user's point of view, however, a good system is one that contains all the information required for a single task on a minimum number of screens and in a format that most closely suits the way the data are used. To achieve this objective, it is necessary to consider in detail the tasks the user is expected to perform, the frequency with which they are performed, and the importance of, or the consequences associated with, task performance. The success of any user-computer interaction is largely a direct function of the designer's knowledge of the user's tasks and requirements.

1.2 Approach to the Project

At the start of the project, discussions with SUMMIT software development personnel and MIDAS development and commissioning engineers revealed the following major points:

> SUMMIT provides a basic set of software procedures to handle functions such as the presentation of menus and the plotting of graphs etc..
>
> Functions and displays that are specific to the requirements of the MIDAS system are programmed by MIDAS development personnel using the software procedures provided by SUMMIT.
>
> The SUMMIT system was at an advanced stage of development. It was expected that the final major software revisions would be completed in a matter of months.

The practice of using standardised software procedures to perform frequently-used functions is common to most software development processes. Although those procedures that are used to drive the

user-interface can never hope to be optimal for the total range of tasks that they may be associated with, they can at least incorporate some of the more general ergonomic principles. From an ergonomic viewpoint, these procedures should also provide sufficient flexibility to enable them to be tailored to the expected user characteristics and information requirements for the specific application.

As SUMMIT software development was already well advanced, the project's first priority was therefore to produce a set of basic software ergonomic guidelines before the costs of making major changes to the software outweighed the perceived ergonomic benefits. For example, a major alteration such as a change in the dialogue method between human and computer from a menu structure to a command language would entail a major revision of the software which would be more difficult to justify at a later stage of software development. It was envisaged that, following the production of this basic guidance, further guidance could be provided to MIDAS development engineers which would take into account the specific requirements of MIDAS user groups. In addition, during the later stages of the project, assistance could be given in implementing this specific guidance into new MIDAS applications.

2. ERGONOMIC ISSUES IN THE DESIGN OF COMPUTER INFORMATION SYSTEMS

2.1 Introduction

The wide range of possible hardware configurations, environments and dialogue styles imply a vast number of potential issues to be considered. As the aim of the project was primarily to provide guidance and design solutions for implementation within the MIDAS surface software system, only those issues that were potentially relevant to the further development and improvement of the current system were to be studied in depth. To enable the identification of these issues, an insight into the current system and the expected operations to be performed with the surface software was necessary before even preliminary basic guidelines could be produced.

In order to identify those software display issues relevant to the MIDAS system, a software development system was obtained which permitted the simulation of the system which was currently supplied to collieries. In addition, there were two MIDAS systems installed and operational at collieries. Visits were made to these sites to observe the displays and interfaces forming the MIDAS surface system within the context in which they were normally used.

2.2 Description of the MIDAS Surface Software System

2.2.1 Hardware

The basic hardware used by SUMMIT and hence also by MSS comprises:

A PDP 11/73 computer with 1 Mbyte of memory and 30 Mbyte of hard disc storage.
A colour graphics terminal with a conventional 'QWERTY' keyboard.
A colour graphics printer.
An interface to the underground transmission system.

The standard display terminal used is a Microcolour M2250 which offers a selection of up to 16 colours at a resolution of 640 x 480 pixels. For

hard copy output, an eight colour ink-jet printer manufactured by Integrex is normally used as it is inexpensive and reasonably accurate. However, faster, more accurate and more expensive printers offering more colours can also be used.

2.2.2 Basic software system

Data is received from the underground transmission system and stored in files on the hard disc. These files are updated such that, when the files are full, the oldest stored data is discarded. Because of this, the time period covered by the data on file depends upon the rate at which new data is received and can vary from a few weeks to several months.

When first accessing the system, or at other times when an activity is completed, the user is presented with a list of options known as a menu from which to select the desired function. This the main or first level menu is shown in Figure 3.

```
                    Surface MIDAS operator's menu facility.
                    ---------------------------------------

Type <BackSpace> to BackUp to previous level, <Escape> to exit menus altogether

1. Examine filed alarms                 6. Plot of data along face
2. Examine current data                 7. Plot of face profile
3. Operators Updated Display            8. Plot of McPos Vs Time for a shift
4. Examine immediate data               9. Plot of data against time
5. Examine filed data

Enter 1 option :-
```

FIGURE 3. Main Menu Display Screen

Selection of any of the main menu items except for item 3 (the operator's updated display) results in the display of further menu pages which guide the user to the data required. Selection of the operator's updated display results in a continually updated display of a selection of data items used for monitoring the current machine status and position.

The further menu pages can be categorised into four basic types used for the selection of:

(a) Data groups.
(b) Data items.
(c) Data access key.
(d) Start time of data.

The data received by the system is classified into one of three possible groups. The first group is data received from the underground transducers on the coal cutting machine (Transducer data). The second is data entered manually undergound on the MIDAS system (Personality data) and the third is data entered manually via the surface system (Configured data). The personality and configured data groups are used mainly during the installation and commissioning periods to provide a record of the changes made to the basic system. It is the data in the transducer group that is of interest to the majority of the system users.

Selection of specific data items from the transducer group is made from the data items available menu page. An example from one system is shown in Figure 4. The data items included depend upon the configuration of the installation and the total number of individual items will therefore vary. The names used to describe the items can be varied and are normally selected during the installation and commissioning phase to suit local usage.

```
        Data Items available on Plant Item S 14's Face, type = Serd
        -----------------------------------------------------------

Select Data Items from :

 1. Boom Oil flow         18. Machine angle (C)      35. Control Avail. RH
 2. Boom Oil flow sts     19. Machine angle (M)      36. Coal type in use RH
 3. Boom Oil temp         20. Coal reading sensor    37. Control Used RH
 4. Boom Oil temp sts     21. Current extraction     38. Signature count
 5. Boom Range pressure   22. Extractn. difference   39. Raw Along Face tilt
 6. Boom Range press sts  23. Haulage direction      40. Raw Boom height RH
 7. Haulage Oil flow      24. Mode switch            41. Raw Coal at sensor
 8. Haul. Oil flow sts    25. Machine position       42. Raw EOF Reset
 9. Haulage Oil temp      26. Predicted coal         43. Midas 5V Supply
10. Haul. Oil temp sts    27. Machine speed          44. Raw Haul. direction
11. Haulage pressure      28. Stored extraction      45. Raw M/c angle (C)
12. Haulage press sts     29. Boom height RH         46. Raw M/c angle (M)
13. Motor Coolant         30. Coal at drum RH        47. Raw M/c position
14. Motot Coolant status  31. Desired Boom ht.RH     48. Raw Roof foll. RH
15. Roof foll. pressure   32. Roof step RH           49. Midas 10V Supply
16. Roof foll. pres sts   33. Steering demand RH
17. A/D status            34. Steering error RH

Enter up to 11 options :-
```

FIGURE 4. Data Items Available Menu Page

The range over which historical data is to be examined can be defined by the use of one of four possible categories known as keys. Data can be accessed by day, by shift, by pass or by shear. Use of the day or shift option allows the selection of a block of data recorded over a given day or working shift. The pass or shear option allows the selection of data based on the physical progress of the machine. A pass is the movement of the shearer from one end of the coal face to the other. A shear is the movement required to cut a complete section or web of coal from the coal face.

Finally, the particular block of data required for display is selected from a menu page which displays the starting time of the available data blocks. The format and number of options on this type of menu page varies depending upon the access key selected. For access by day, the available dates are displayed. Selection of data classified by shift is made from a menu which presents the dates and shift names of the data available (e.g. mornings, afternoons or nights). For access by pass or shear, the date and start time (in hours and minutes) for each pass or shear stored in the files is displayed.

2.2.3 Information displays

The data can be displayed in textual form or in one of several different graphics formats. The display system is based upon a standard graphics package which can allow up to 100 different plant items to be displayed simultaneously.

The selected transducer data can be displayed on the terminal screen in a numerical format. In its alphanumeric display mode, the terminal is capable of displaying 24 lines of text in 80 or 132 columns. In this manner, data from up to 11 transducer items can be displayed at any one time. Numerical information is listed in columns on the screen with the first column being used to display the time at which the data was recorded. If more than six items are requested then the display screen would be used in its 132 column mode to enable all the selected items to be listed at the same time.

Graphical displays of the transducer data are produced by selecting options 6 through 9 from the main menu. Options 6 and 9 would produce a plot of any of the selected data items against either the machine position on the coal face or against time. Up to four data items can be selected for display at any one time. If the data from the selected items was measured in the same basic units, for example if they were all measures of temperature, the user could have all of the selected items plotted on a single graph. Otherwise, up to four separate graphs can be displayed on the screen at once.

When graphs are to be plotted a series of supplementary questions are asked to determine the layout and scaling to be used in the production of the display. For example, when data is to be plotted against the machine position on the face (option 6 on the main menu), the following questions would be asked in turn, to determine the scaling of the X axis:

```
Autoscaling on along face axis ? [Y/N] (Default [No]):-
Enter start point for plot     - [0.0 to 350.0] (Default [0.0]):-
Enter end point for plot       - [0.0 to 350.0] (Default [350.0]):-
```

If autoscaling is requested, the subsequent questions would not be asked. All supplementary questions have the same basic format as those shown above. Thus, following the basic text of each question, an indication of the range of acceptable replies is given in square brackets. For example, "[Y/N]" in the first question above indicates that a Yes or No answer is required and the user may respond by entering a letter "Y" or a letter "N". In the other questions, the range indicator "[0.0 to 350.0]" shows that a numerical value in the range 0 to 350 should be entered. Following the range indicator, a default value is normally shown. This is the value that would be automatically entered by the system if the user simply pressed the enter key.

2.3 Ergonomic Issues Identified from an Initial Evaluation of MSS

From examining the system described above, it was possible to identify those ergonomic issues in software design which were relevant to the MSS system. Consequently, the literature in the following topics areas was reviewed to provide the basic information for the production of software design guidelines for use by the MSS development staff.

- Dialogue Design
- The Use of Colour on Displays
- The Layout and Structure of Menu Systems
- The Use of Graphs and Charts
- The Use of Numerical Tables
- Text on Visual Display Terminals
- The Use and Construction of Abbreviations

Equally importantly, it was possible to exclude aspects of software design within these topic areas which were not expected to form a part of any current or future MSS system. For example, considerable current interest has been expressed in the use of icons and other symbol-based

menus for accessing parts of a system and such 'user-friendly' approaches have been widely adopted within the computer industry. However, development of an icon-based menu system on the type of hardware currently employed to run the MSS system, would be impractical. Changes to the MSS system that resulted from the introduction and use of the resulting guidelines are reported in section 5.

3. DERIVATION OF GUIDELINES FOR THE DESIGN OF COMPUTER INFORMATION SYSTEMS

3.1 Introduction

Having identified those topics where guidelines for MIDAS software design were required, the next stage was to generate the basic principles which would be used in formulating the guidance eventually provided. Principles relating to many elements were already available, either in established good custom and practice or in existing guideline documents. However, there were a number of issues either where principles or guidelines had not been established or where there was an element of diversity or conflict amongst differing sources. In these cases, it was necessary to examine the underlying experimental literature in order to develop suitable principles and guidance. This section contains an overview of the literature on the relevant ergonomic factors associated with computer systems and human:machine interaction. The information obtained from this was then used, in conjunction with the established sources referred to above, to formulate a set of general purpose guidelines to assist in and encourage the use of ergonomic principles in the design and development of computer-based information systems. The resultant guidelines are given in Appendix A. As stated earlier, both this overview and the ensuing guidelines were only intended to cover those design aspects relevant to the current and anticipated characteristics and hardware of the MIDAS surface system. Thus, for example, the use of a QWERTY keyboard and an 80 column by 24 line visual display unit was assumed throughout, as this was the hardware used on the MSS system.

3.2 Dialogue Design

3.2.1 Introduction

A user needs to feel that the computer is there as a tool to be used. This feeling is determined in part by the tone and sequencing of the discourse between the user and the computer. Users of an interactive system quickly build up a feeling of style and quality of the system. The term 'dialogue' in this context denotes a set of input and output

procedures with which a user communicates with a computer system, and vice-versa.

3.2.2 Dialogue quality

Actual knowledge (as opposed to opinion) about user-perceived quality is scarce. A first step towards measuring this elusive construct is to identify relevant system properties and user abilities (Embley and Nagy, 1981). One approach to this is by direct observations of users on existing systems. Kennedy (1975) observed a large sample of clerical and secretarial staff learning to use an interactive system. Initially this began as a controlled experiment to investigate factors affecting learning, such as attitude towards computers, availability of manuals, self-learning from the system, and verbal assistance from an instructor. None of these factors was statistically significant, but observations did lead to system improvements and more effective training. Kennedy claimed, at least for the system he observed:

(a) self-teaching through trial-and-error with machine feedback seemed to be the most effective;

(b) subtle distinctions in technical terminology were inadequately explained;

(c) anxiety decreased learning, particularly in the subject's first session with the computer.

Obviously, designing a tightly controlled experiment to run in the field, or taking advantage of a "natural" experiment, raises special problems for the experimenter. But the observations do yield new hypotheses that can be tested.

A classical approach to the problem of identifying system properties relevant to dialogue quality was taken by Dzida et al (1977 and 1978), who used a combination of questionnaires and factor analysis to arrive empirically at the 'dimensions' of user-perceived quality. Seven factors were associated with 44% of the variation in the data. These

were labelled, in descending order of importance:

(a) Self-descriptiveness: e.g. providing help and guidance to explain the actions required next.

(b) User control: e.g. allowing the interruption or cancelling of commands.

(c) Ease of learning: e.g. not assuming a high level of prior knowledge of computing.

(d) Task-adequate usability: e.g. not making tasks unnecessarily complicated by requiring the user to undertake system management functions,

(e) Correspondence with user expectations: e.g. responding consistently.

(f) Flexibility with task handling: e.g. not imposing excessive structural or control limitations in relation to the task being executed.

(g) Fault tolerance: e.g. explaining errors rather than responding with an obscure error number or message.

The importance of some factors varied widely depending on specific user groups. For instance, infrequent users felt that ease of learning was much more important than did regular users. (The importance of designing for operator experience is discussed further in section 3.2.4 below.) These results indicated that this is a promising approach towards developing an objective measure of user-perceived quality although, in view of the unexplained variance and dependence upon type of user in this study, much more research is needed.

3.2.3 Consistency

There is a considerable body of psychological evidence that people can

learn with little conscious awareness (see, for example, Thorndike and Rock, 1934). One implication of results like these is that users will infer underlying principles of operation even if they are unaware of doing so (Singer, 1977). One of the strategies adopted by users initially getting to grips with a system is to extrapolate from early examples to new situations. So if the inferences the user makes about the system are true sometimes but not always, then learning is impeded and the amount of errors and frustration increased. The principle of consistency applies to many factors, such as the division of a VDU screen into dedicated areas and the use of coding conventions (e.g. colour, symbols).

3.2.4 Dependency on operator experience

Duration, frequency of use of the system and training influence the appropriateness of different dialogue methods. It is intuitively obvious, for example, that a menu structure is better for naive or infrequent users than a command language structure, since a reminder of what can be done is shown on the screen. At one extreme, if users are not at all familiar with a keyboard and use the system infrequently, then the interaction needs to be tightly constrained and the acceptable 'language' or response always made explicit. For casual or infrequent users, ease of learning is more important than for experienced users (Dzida, op cit). A user working with a computer several hours a day can build up a full language for interaction; full instructions at every step in the dialogue are not therefore necessary. If the target user group is likely to cover a range of experience levels it may be desirable to allow a choice of dialogue methods (e.g. menus, form-filling, command languages). Cuff (1980) noted that, for casual users, a fixed menu organization, in which the user selects in a simple manner one item from a short list, avoids many of the sources of error inherent in a formal language interface.

3.2.5 Error correction

When entering data or giving instructions an operator inevitably makes some mistakes. Good design reduces but does not eliminate their

likelihood. Hence, users should always be given the opportunity to correct an error or modify an input.

Errors of misremembering occur much more frequently with casual users than with dedicated users. Katter and McCarn, reported by Martin (1973) described inexperienced users as coming to a retrieval system afraid that they will do something wrong, but expecting the system to catch them when they stumble. They need to feel that "they will never be left in limbo" (Gaines and Facey, 1975).

Maguire (1982) pointed out that if an incorrect dialogue path is taken, it is necessary for this to be spotted by the user as early as possible before many subsequent inputs have been made. Gaines and Facey (1975) discussed this problem and stated that if the computer's responses are designed to identify the activity taking place, then the ability of the user to recognise errors is strengthened. Appropriate action can then be taken to exit from the activity.

The need for well-designed error messages is also widely recognised. Schneiderman (1979) suggested that they should be understandable, non-threatening and low-key. Maguire (1982) gave an example. The message:

ERROR 435-NUMBERS ARE ILLEGAL

would be better replaced by the simple response:

MONTHS ARE ENTERED BY NAME

which tells the user what is needed to put things right.

3.2.6 System response time

A potential source of frustration is the computer's response time to commands. In general, a delay in the computer's response is acceptable only if it is in proportion to the perceived difficulty of the requested task. An immediate response is not always required. Most reported work concerning the psychological reaction to computer response time stems from the work of Miller (1968). Unfortunately, Miller's suggestions

were not supported by any experimental evidence. Although, in retrospect, the authors' opinions were affected by the slower speed of computers at that time, the statements still seem valid in principle.

Essentially, Miller saw two factors at work: firstly, users expect certain response speeds, and secondly, humans seem to have a sense of task "closure" - a temporary sense of completion after a clump of activities. During a clump of activity, information is held in short term memory. Any interruptions or delays in achieving closure disrupt short term memory and hence cause frustration. The pressure for closure means that users, especially novices, may prefer multiple small operations to a single large operation. Not only can they monitor progress and ensure that all is going well, but they can release the details of coping with early portions of the task (Shneiderman, 1979).

Miller categorized a large number of human tasks into seventeen types. The appropriate response times were established on the basis of the most probable cognitive processes involved and on the assumption that the user is operating interactively with the system. The response time was loosely defined as the elapsed time between a user request and a reply that enables continuity of thought. Thus, the time to complete a reply to the user was included in the response times recommended. Delays longer than five seconds reduce performance by increasing frustration and the possibility of distraction or error and, as response time extends to ten or fifteen seconds, continuity of thought becomes difficult to maintain.

Newman (1969, quoted in Umbers, 1976) investigated the effect of delaying the arrival of information on an interactive graphics display system. Delays were introduced when an enlargement of a graph or a return to the original display was required. It was found that delay times of greater than two seconds caused a disproportionate increase in task completion time. In Miller's terms, this delay came before task closure, hence presumably the disproportionate effect.

When a user asks for complex calculations (and there is an awareness of this) then there is more tolerance for a delay between request and

response. But consideration of the delay times alone is often not sufficient. For example, a predictable but slightly longer delay is usually preferable to a shorter but highly variable delay. Carbonell et al (1969) were the first to point out that it is the variability of delays and not their duration that most frequently distresses people. Experiment has confirmed (Miller, 1977) that increasing the variability of response time gives poorer performance and lower user satisfaction. Holding responses to minimise response time variance may actually improve user performance and satisfaction. Martin (op cit) suggested that, as a rule of thumb for delays of up to 15 seconds, the Standard Deviation of the response time should be no more than about half the Mean.

Shneiderman (1979) suggested that for response times over about 15 seconds the computer should inform the user of the time required. Preferably the display should give some dynamic indication that processing is continuing such as a count-down clock arranged to reach zero on completion (suggested by Spence, 1976), or some other display of time to completion. Even if the response is ready earlier the system should continue to count down to zero. A static message may mislead the user into thinking the task is continuing when in fact the system has crashed and is at least unnecessarily unnerving.

If response delays of more than 15 seconds are necessary, then the task should be designed to free the user from activity (ie no interaction for the delay period, no necessity to remember where in the task the user had got to) so that the user can do other work and return to the display when it is convenient. If users know that a delay period is necessary then, according to Grossberg et al (1976), they alter their strategy to make use of the time (e.g. mental preparation for the next step) so that increased mean response time need not necessarily have a direct effect on time to complete a task.

Since performance is adversely affected by delays, the display designer might be tempted to use high density information displays, "particularly if unanticipated contingencies are prevalent" (Umbers, 1976). However, Baker and Goldstein (1966) found that displaying information that has

only potential relevance to a problem-solving task is ineffective and degrades performance. The authors suggested that, instead of cluttering displays with useless information, one should place emphasis on developing techniques for more rapid retrieval of information.

3.3 Colour

3.3.1 Introduction

The addition of colour to screens can add a new dimension to utility. As a formatting aid, colour can assist a person in understanding the logical structure of the data on the screen. As a coding aid, it can help establish the meaning of the data or information displayed. Only ergonomic factors are discussed here. Other factors such as display technology, system costs and commercial appeal of colour are largely disregarded. Sections 3.5, 3.6.2 and 3.7.6 also contain some discussion of the use of colour in specific situations.

Little research that gives concrete guidelines on the use of colour in VDU displays is currently available. The most thorough review of research on the effects of colour in displays is that of Christ (1975), although it includes little concerning VDU-generated displays. DeMars (1975) also reviewed the area and drew a few practical guidelines. Robertson (1979) provided more discussion of some practical guidelines based on experience using colour displays. Galitz (1981) drew these and other sources together. While these references are short on experimental validation, they do provide some useful guidance on how colour can be used in screens, and form the basis of the discussion following.

The use of colour in interactive displays can be considered in three different ways:

(a) as a supplementary coding method to others, such as spatial location, labelling, shape and size etc.;

(b) as the sole or unsupported method of coding display information,

e.g. colour changes to show change of status,

(c) to increase the aesthetic appeal of the display, without necessarily enhancing the function of the display.

When colour is used with another 'code' such as text labels, symbols, etc, then colour is considered to be supplementary, as it is not the only means by which the information is being conveyed. For example, if a status label changes from 'stopped' to 'running' and also from red to green, then colour is being used as a supplementary code to the text label. Supplementary coding is a very effective way of increasing the efficiency of display usage, provided the use of colour has been planned with respect to other methods of obtaining information used in the display.

When colour is the only form of coding this means that the display does not use any method other than colour to convey information contained in the display. For instance, if the status of an item of equipment on a display is shown by its colour (e.g. green is running, red is stopped) and the display shows this information in no other way, then colour is the only form of coding for its status on that display. Unsupported colour coding is a very effective method of obtaining information related to some tasks, provided the colour codes are known, relevant and limited in number.

3.3.2 Colour-coding

Colour can be used as a visual code to identify:

- kinds of data
- sources of data
- status of data
- order of operations

The colour-coding scheme must be relevant and known (Galitz, 1981). A colour code can show what category the data being displayed falls into. To do this it needs to have a meaning for the screen's user. A properly

selected colour-coding scheme allows a person to identify a relevant category quickly without having to read all the data. Passavant (1970) suggests that colour permits focussing of attention on the category while the remaining data are excluded from attention. DeMars (1975) calls this class coding. For instance, Passavant made an unreferenced claim that by encoding displayed data in five colours, counting time for all items in a given class can be reduced by 50 to 70% below the corresponding time for a single colour display. Counting errors are also reduced by a factor of approximately 75% (Passavant, 1970).

Unfortunately, the number of colour-coded categories cannot be increased indefinitely. Even though people with normal colour vision are able to discriminate a great many colours, only a limited number of colours can be recognised consistently when colours are presented singly without any reference. DeMars (1975) put this figure at 10 for ideal conditions. Under practical conditions, Demars (1975) stated that probably no more than five colours should be used if reliable colour identification is required. Teichner (1979) set the practical limit at between four and six, though this was purely an opinion, partially based on technological limitations at the time. Bailey (1982), in an unreferenced recommendation, suggested that no more than eight colours should be used for colour-coding. This statement was probably based on the work of Jones (1962), who reviewed a decade of research on colour-coding, and recommended the same maximum figure.

3.3.3 Aesthetic appeal

It is generally accepted that the use of colour may increase the interest and the commercial appeal of a display. On very simple displays, its use for aesthetic reasons is unlikely to have any adverse effects on task performance (although it will not improve performance either). However, as display complexity increases, so does the potential for the inappropriate use of colour to affect performance adversely. This is mainly because colour is such a powerful coding medium that it tends to be processed at the expense of other coding methods. The eye and brain combination recognises colours at a glance, while recognition of other codes demands a more detailed examination of

the data (DeMars, 1975).

Some of the possible adverse effects on task performance are summarized in Krebs (1978), though no experimental evidence for these points is offered:

(a) Colours can have specific meanings for the user which were not intended by the designer. For instance, the colour of a symbol is noted whether or not the colour has any task-related meaning.

(b) Display items shown in the same colour may be visually grouped in a way that is unrelated to the task or is in conflict with another task-related group of items.

(c) Indiscriminate or unwise use of colour in one display may interfere with the attention-gaining powers of colour in another display.

Dooley and Harkins (1970) have shown experimentally that where colour is used purely decoratively or aesthetically on displays such as graphs, it can have a motivational or attention-getting effect. This effect may be desirable in situations where the screen presentation may otherwise be ignored. Weak functional use (coloured bars) did not have any strong effect on understanding, or learning from, the presented material.

3.3.4 Selection of colours

Important considerations in colour selection were summarized by Galitz (1981):

- Terminal colour capabilities
- Consistency
- Compatibility with expectancies
- Discriminability
- Frequency of use and importance
- Relevance and confusion

From a practical standpoint the colours used on most displays are

variations on red, green and blue, plus white. Colours selected from other portions of the spectrum provide greater opportunities for between-terminal differences. Some terminals add turquoise, yellow and pink to these, for example. These have been described as being adequately discriminable although confusions can occur between blue and turquoise, and white and pink (Robertson, 1979).

Galitz, (1981) recommended that consistency should exist within a screen, an application, and a set of applications used by a person. Colours used as codes are expected to have some meaning which should be compatible with experiences. Broad definitions of colour meaning provide less opportunity for confusion (such as red indicates there is a problem). Compatibility with expectancies means using colour associations that already exist in a person's job or that exist in the world at large (Galitz, 1981). Colour codes using different meanings will be more difficult to use, as colour meanings which are ingrained are difficult to unlearn.

A number of other uses for coloured displays can also be identified. For good colour discriminability, colours should be selected that are widely spaced along the visual spectrum. For emphasis and separation, contrasting combinations are available, such as red + green, or blue + yellow. Alternatively, if the application requires it, warm and cool colours may be used to create a depth effect with warm colours (reds, oranges) tending to advance in space whilst cool colours (blues, greens) tend to recede in space (Tedford et al, 1977). Even when a single colour is used different saturation or intensity of colour can be used to create contrast or depth (Truckenbrod, 1981). Different colours are compatible with different sizes of display area. For example, colours with a low comparative luminance such as blue are acceptable for large areas but in small areas, e.g. symbols, may be difficult to discern (Galitz, 1981). It follows from this that, when different colours are used either in close proximity or crossing each other, care should be taken to ensure that bright colours do not mask others.

Finally, eight percent of the male population have defective colour vision. Rather less (under one percent) of the female population also

have this problem. For example, people with a red and green colour deficiency (the most common) have problems distinguishing yellow-reds from yellow-greens and brownish reds from brownish greens, although some combinations are distinguishable by luminance. However, DeMars (1975) claims that the factor is not significant enough to influence the decision whether to use colour in an information display system. Screening procedures to identify users with serious colour vision defects would only eliminate three to five percent of the total screened. DeMars therefore recommended that the colours used should be chosen to accommodate mildly afflicted colour-deficient people, and that other forms of coding should be used to supplement colour if confusion is likely or the application is critical. A full explanation of the varieties and degrees of colour vision deficiency is given in DeMars, 1975).

3.4 Menus

3.4.1 Introduction

Two common applications of the use of menu systems on computers can be identified: searching information retrieval systems, and issuing commands or defining options either for display of information or for processing. Others are discussed in Card (1984). In the first of these, the user's task is a form of semantic matching: the goal is known, and the task is to match the closest semantic labels offered on successive menus, working from a general to a near-exact match. In the second, the user is usually more familiar with a restricted range of commands, options or selections and has only to choose one (or more) to reach the desired goal.

For the sake of simplicity these two types are referred to as information retrieval menus and command menus in the discussion below, although it is recognised that this is to some extent an artificial dichotomy: sometimes the 'pure' information retrieval and command types are combined. For instance, in the course of searching for information to display, a user might be required to define or select the manner in which the target information is displayed.

Giroux and Belleau (1986) made this distinction, crediting it originally to Card (1984) who studied only command menus. In the case of command menus, due to the limited number of commands and the frequency of use of the menus, the menu items are usually known to the user and the task comes down to a simple locating process. In the second case, given that the menu items are categories of information, the selection process should depend on factors such as familiarity and semantic distance, factors known to play a role in other categorisation tasks (Lachman et al, 1979).

It might be expected that these two types would require different design rules. For instance, Giroux and Belleau (1986) speculated that semantic clustering may be better for information retrieval menus than alphabetic ordering. On the other hand, Card (1984) found that command menus were searched faster when arranged alphabetically than when arranged categorically or randomly, although differences decreased with practice and were no longer reliable at the 4th block of 43 trials.

3.4.2 Advantages of menus

Among the purported advantages of menu-based retrieval systems is that they structure the user's task in several ways (Allen, 1982). First, lists of currently available options are always displayed, so even naive users are not at a complete loss for what to do. Furthermore, tree organizations provide an efficient and sufficient way to move through the database and a possible way to convey relationships between categories of objects.

A menu selection system requires little user training and has the advantage that the actual process of working through the menus lets the user know of other available options and information (Shneiderman, 1978).

3.4.3 Disadvantages of menus

Dumais and Landauer (1984) outlined some of the problems of menus: they

can be tedious for experienced users, not all kinds of information are suited to hierarchical presentation, and the search and access routes depend on a rigid, partly arbitrary, organization imposed by system designers. Furthermore, the initial process of learning how the information is organized may put considerable strain on the memory capacity of new system users, especially when goal items are as many as five levels deep in the menu structure (Engel and Granda, 1975; Miller, 1981).

Even though information retrieval menus are supposedly easy to use for novice users, their performance characteristics can easily fall considerably short of what one might wish. For example, Lee et al (1984), examining information retrieval menus, found that:

(a) users failed to achieve their goal on 23% of occasions;

(b) users had a 23% chance of going off on the wrong path at each decision point in the menu structure;

(c) more menu page accesses than necessary were made to reach the goal;

(d) search times for each page were several seconds, so that total search time for a deep menu structure may be prohibitively long;

(e) with practice, users find a menu system increasingly tiresome and tedious.

These problems were caused mainly by errors on the top level menu page and the opportunity for getting lost or making errors in the menu hierarchy under it (Lee et al, 1986a). For large information retrieval systems (i.e. hundreds of pages) it may be better to allow the top level menu to be bypassed by using a keyword system (Lee et al, 1986b). At least comments from naïve users should be sought before implementing a new menu system (Lee et al, 1984).

3.4.4 Categorizing and naming

Dumais and Landauer (1984) believed that there are two main classes of problem in the design of menu-based retrieval systems:

(1) Inaccurate category names:

(a) Category names not always descriptive
- vague (e.g. "other")
- hard to name categories.

(b) Mismatch between system designer's and user's interpretation of category names.

(2) Classification:

(a) Overlapping and fuzzy categories.

(b) Classification on the basis of one or a few dimensions or aspects.

Lee et al (1984) found that the addition of descriptive phrases to the options on the top level menu significantly improved performance. Similarly, Schwartz and Norman (1986) found that a revised top level menu in which options were rephrased to increase item distinctiveness resulted in improved performance in terms of time taken and efficiency.

3.4.5 Navigation

Although a hierarchical menu structure has several advantages for novice or infrequent users, there is great potential for confusion and disorientation when menu structures are large and complex. New or infrequent users are likely to find themselves lost in the structure of the hierarchy (Billingsley, 1982). This can produce several negative results, including frustration with themselves and the system, loss of time, and possibly a disinclination to continue to use the system. If the actual organization of the information does not match the user's

mental model of it, or one has not yet been built up, then efficient information retrieval is even more difficult (Cuff, 1980).

One way to help overcome this problem is to assist in the generation of an accurate mental model from the start by giving the user a representation of the menu structure, either on-line or contained within documentation. McGee (1976) introduced the concept of "picturability" in a discussion of user criteria for data model evaluation. He suggested that the display of structures in pictorial form would be particularly helpful for the initial learning of data models. Billingsley (1982) tested this empirically. It was found that exposure to a pictorial representation of the structure of a menu system helped subjects to develop a workable mental model of the way data elements interrelated. It also aided subjects in remembering how to find target data for a considerable time after the map was no longer available.

3.4.6 Number of menu items per page

In an empirical test of information retrieval menus, MacGregor et al (1986) showed that the optimal number of items per page was four to five for novice users. These numbers resulted in the shortest search times, the highest success rates and the highest preference rankings. This was consistent with previous estimates, which suggested optimal values of between four and eight for a wide range of videotex operating conditions (Lee and MacGregor, 1985). However, in their mathematical model for optimizing menu size on the basis of search time (Lee and MacGregor, 1985) computer response time is included. Hence it might be defensible to have larger menus if a system is slow between pages although, of course, this delay is not in itself desirable (see section 3.2.6). An increase in computer response time to four seconds between menus increased the optimum in terms of search time to seven items. The authors stressed that their findings applied to the use of large videotex systems and that they were unlikely to apply, for instance, to daily use of a computer command menu.

For command menus, there are empirical grounds for believing that the optimum menu breadth may be much more. Snowberry et al (1983) compared

menus with 2,4, 8 and 64 alternatives to access a database of 64 items. They found the 64 condition resulted in the shortest search times (with success rates equivalent to the 8 condition). On the evidence so far, a minimum of eight options per page is optimal, with some indication that the optimum could be considerably greater than eight. Their database was small (64 items), subjects received a high degree of exposure to all menus, and the tasks frequently involved simple visual search, rather than category judgement. These factors are more typical of command menus than information retrieval menus.

3.4.7 Grouping of menu items

Paap and Roske-Hofstrand (1986) suggested another circumstance in which the optimal breadth may become much larger than the four to eight range. This occurs if items are grouped into categories, so that users can first locate the relevant category and then the relevant item within the category. They suggested that the optimum lay between 16 and 78 with grouping, with four to nine items in each group. Parkinson et al (1985) provided some interesting results on the organization of grouped menus. In menus where words belonging to the same category were grouped together on the display, search time was significantly faster when grouping was by column, rather than by row. Spacing between groups also produced an improvement. No advantage was found for alphabetical ordering as opposed to categorical ordering within groups, given categorized menus. Menus in which the entire array was arranged in alphabetical order were searched with rates similar to those for categorized menus with spacing and faster than categorized menus without spacing.

3.4.8 Positional constancy

One of the most cited screen design guidelines is positional constancy. This guideline prescribes that usability is enhanced if the physical screen location of a particular piece of information remains constant for all screens that belong to the particular application. Teitelbaum and Granda (1983) investigated this assertion experimentally on a menu-driven information retrieval system. Each display screen contained

five standardised pieces of information: a title, a page number, a topic heading, an instruction line, and an entry area. Results showed a saving in time to respond to questions about this standard information when its position was held constant, and an improvement with repetitions.

3.5 Graphs and Charts

3.5.1 Introduction

Graphs and charts are generally regarded as most appropriate for showing qualitative aspects of data although they are not suitable if the prime purpose is to show exact numerical or quantitative data. Displaying qualitative aspects of the data in this way, allows the user to grasp the meaning or significance of the data in some particular context. The presentation of exact data must at most be of secondary importance. Usually the user is expected to make comparisons and appreciate patterns in the data but not to perform exact calculations. For example, graphs and charts are good for:

(a) showing trends;
(b) making comparisons;
(c) spotting deviations from the normal;
(d) showing the division of a whole into parts.

No one graphic format can be considered to be universally superior. But, although some formats can be interchanged, there are limits. Each format has its domain of application, which may overlap the domain of other formats.

Hartley and Burnhill, (1977a) identified a number of factors which are said to inhibit the general legibility of graphical aids:

(a) Reverse video lettering.
(b) Words set at an angle to the horizontal.
(c) Haphazardly arranged lines connecting labels to reference points.
(d) Unprincipled variety of typestyles and sizes.

(e) Functionless use of colour.

3.5.2 Simple graphs

The simplest form of graph shows values of one variable against another. A normal time-history graph is an example, where the values of a variable are plotted on the Y axis against time on the X axis. A simple line graph is usually the best way to display data when the user's task is to compare data. For example, Schutz (1961a) has shown that the simple line graph is superior to other types, such as the bar chart when the user's task is to extrapolate, interpolate, compare or classify trends in time and not to read off exact amounts. The only exception is when there are few time periods with large changes from one period to the next, in which case it has been suggested that a bar chart may be effective (Anon, 1981).

Cleveland et al (1983), suggested that scatterplots are generally only suited to a scientific audience. Their purpose is generally to illustrate the relationship between two variables, often to show the degree of linear association. As even statistically sophisticated users' perceptions are affected by irrelevant factors, such as colour and choice of scale, Cleveland et al recommended that scatterplots should not be shown without numerical values of association. Also, if several scatterplots are to be compared, the scales should be arranged to make the point-cloud sizes similar. It has been suggested (Anon, 1981) that one should not use a scatter-plot to try to show that a relationship does not exist, since most viewers will find a pattern whether there is one or not.

3.5.3 Multiple-line graphs and multiple graphs on a page

It is possible to show several lines on one graph or to have multiple graphs on one page or screen. Schutz (1961b) studied the sources of confusion when several trend lines were presented on the same graph. The author varied the number of lines, the coding of the lines, and the graph-reading task. Firstly, twenty-five kinds of black-and-white line codes were devised and the results presented as a 25 x 25 confusion

matrix. On the basis of this, the recommendation was made that line codes for graphs should be chosen so as to minimise confusion! Following this, four codes were selected, no one of which was ever confused with the other three. The main set of experiments then examined these variables: multiple line or multiple graph, two, three or four lines, low or high confusion (extent of line crossovers), point-reading or comparison tasks, and colour or black-and-white lines. The subjects' task was to read or compare the highest value on the vertical axis for specified positions on the horizontal axis. Time taken to complete the task was the main measure of performance, with ten subjects who were professional engineers.

Analysis of variance yielded the following results:

(a) For reading points, multiple lines and multiple graphs are equally good, but for comparison tasks the multiple line is always superior, although, as Umbers (1976) pointed out, a similar result might not have been obtained if subjects had been required to read intermediate values rather than the highest.

(b) Colour-coding generally improved performance, especially for multiple line graphs, but this effect was not of prime importance.

The number of lines on a graph was also a significant factor which interacted with the other variables studied. For practical reasons there has to be a limit on the number of lines shown on one graph. According to Szlichcinski (1981) this limit could be as low as three if they cross frequently.

3.5.4 Bar charts and pie charts

The bar chart is generally suited when the user's task is to compare the relative quantities of a number of different categories of items or to read the approximate numerical value of each. Much of the research leading to this conclusion was reviewed by MacDonald-Ross (1977). Since the turn of the century, many authors have given their opinion that bar charts are superior to pie charts for comparing quantities in categories

because the eye makes comparisons of length more easily than area or volume. Several authors have tested this opinion empirically, but the first whose research was not experimentally flawed (according to MacDonald-Ross) were Croxton and Stein (1932). Their main conclusions were:

(a) Comparisons based on bar charts were more accurate than those based on circles or squares.

(b) Comparisons based on circles or squares were more accurate than those based upon cubes.

It has been suggested, that if a range-graded scale or key is used, showing every step in the scale of circle sizes (as found in some atlases) then this removes or reduces the accuracy advantage of bar charts and allows the practical size advantage of pie charts over bars to be exploited (Meihoefer, 1973).

Apart from the bar-circle controversy, there are very few published comparisons of bars with other forms of presentation. Culbertson and Powers (1959) found that:

(a) Bar graphs are much easier to read numerical values from than line graphs.

(b) Grouped bars (each element originating from the base line) are easier to read than segmented bars (where a single bar is subdivided) which are very difficult.

(c) The elements of bars or graphs should be labelled directly, rather than indirectly by key or grid. Horizontal bars give room for labels and numbers on or near their ends.

This last conclusion was supported by more recent opinion (Anon, 1981).

3.5.5 Scales

In some cases, choosing the scaling (or allowing autoscaling) to make the plotted line fill the graph exaggerates variations in the data by increasing the slope of the line between points. An interesting study by Simcox (1984) studied the relationship between the slope of plotted lines and subjects' assignation of the line to the semantic categories "slightly increasing" and "sharply increasing". The crossover point from one category to the other was at about 30° of line slope. Perhaps surprisingly, the 95% confidence limits for this crossover were less than ±2°.

The normal practical implication of this work is that one should try to arrange the graph so that normal variations in the data (not sharp or abnormal changes) are represented by line slopes of no more than about 30°. Above this angle, users are more likely to perceive the line as sharply changing, when the data do not warrant this interpretation. However, as Simcox points out, in a setting such as process control where a parameter may have to be held at a very tight tolerance and its measurement presented graphically, changing this aspect ratio to emphasise small changes could be desirable.

If there is a large amount of point-to-point variation that has no particular significance for the user, then in most cases it may be worthwhile considering smoothing the data or plotting an interpolated line to show hidden trends or patterns. However, Anyakora and Lees (1972) have shown that in some applications, for instance again in process control, an operator may learn a considerable amount from variations in the data; for example, instrument malfunctions may be detected early. These last two points emphasise the importance in the design process of examining the way in which the display is to be used.

3.5.6 Coding in graphs and bar charts

The term coding refers to the use of a visual cue such as colour or shading to indicate different categories of areas, lines or bars on a chart. Section 3.3 gives details the use of colour for coding. The

related subject - using different symbols to represent different categories of points in line graphs - was covered in section 3.5.3. Shading or hatching is an obvious choice for coding information at a nominal level of measurement, either to show areas on a graph or to distinguish categories of bars. There is no objection based upon research to the use of pattern as a code, but it has been recommended (Anon, 1981) that the patterns chosen are not too garish. In addition, some VDUs or graphics systems may not reproduce some patterns well. Patterning can also be used to represent different levels of an ordinal variable. It has been suggested that if there is a logical order to the shades then the darkest pattern should be used for the highest extreme and the lightest for the lowest extreme of the order (Anon, 1981). However, this guideline was given with reference to graphs presented on paper, not VDUs. It seems reasonable to assume that "darkest" would translate to "most dense" when applied to presentation on a VDU which would avoid ambiguity when a graph is shown on a VDU with a black background, although this suggestion has not actually been demonstrated by research.

3.6 Tables

3.6.1 Introduction

The work reviewed here relates primarily to those tables defined as static collections of numerical data organized and classified into columns and rows. No research reports relating to the design of specialised forms of table, such as dynamically changing lists, spreadsheets, etc, could be found. However, it appears likely that most of the findings discussed here are relevant to such kinds of table. In section 3.5, it was noted that graphs were not well suited to the exact presentation of numerical data. Tables are one of the most compact ways to present such data. Their only serious weakness is their abstract nature. MacDonald-Ross (1977) claimed that even quite sophisticated people need time to get the main points from a table and less educated people often cannot read tables at all. The choice of table involves a complex trade-off between compactness, exactness, and ease of use. The best way to present a table depends upon the purpose it is to fulfil.

Tabled data can be needed for several different purposes. For instance, a table may be required:

(a) for exact numerical comparisons;
(b) for rapid look-up of one or a few figures;
(c) 'for the record'.

The layout and design of the table should therefore reflect its intended purpose. For example, if the purpose of providing a table is to allow a quantitative comparison then a good table should show the patterns and exceptions in it. Similarly, if a table is needed to allow a quick look-up of a value then the organization of the rows and columns should facilitate this. In general, as the number of conditions presented in a table increases, the table becomes harder to understand and use. Sometimes it is better to simplify presentation by creating two or more smaller tables.

3.6.2 Principles for the design of tables

Work by Ehrenberg (e.g. 1977) has clarified ideas for the design of tables whose purpose it is to summarize or present numerical data. Bailey (1982) also reviewed some guidelines from human factors literature for the design of tables which largely echoed those of Ehrenbergs'. Ehrenberg argued that the design of tables can be markedly improved by a few simple principles each of which are discussed below. The rules were supported by informal trials and some formal tests, by examples and by discussion of the objections raised by fellow scientists.

Ehrenberg's first rule was that data should be presented rounded to two significant or effective digits, where "significant" or "effective" means digits that vary in that kind of data. It was argued that one of the main points of giving data in tables was to allow quantitative comparison and that as most people can only do mental arithmetic efficiently with one or two digits it is only obstructing the user to report figures to more than two significant figures. If a table of exact data is needed as a record then this should be given separately.

The same table should not be expected both to give an immediate understanding of the data and also to form an exact record. If different categories of data within the table have greatly different numerical ranges or sizes, then it was recommended that they should be rounded to two significant figures <u>in their own context.</u> This avoids over-rounding when different groups of figures vary greatly in size.

In defence of these apparently drastic views on rounding the author made several points:

(a) Instead of asking "Is it possible to round these data to two significant figures" one should ask if there is some specific reason why one should <u>not</u> do so.

(b) No information need be <u>completely</u> lost by rounding. Basic data records can be kept unrounded.

(c) Rounding errors are trivial in the context of the size of the remaining data. Hoping to explain variation to the third digit (less than 1%) is absurd.

Ehrenberg included a number of principles relating to the structure of tables. It was suggested that some form of summary of the data, such as an average or a total, should be placed at the ends of rows and columns. Such an approach can help the user to see patterns in the table more quickly. More assistance can be provided by placing the important elements into the columns as figures are easier to compare in columns than rows, especially for a large number of items. The improvement is a perceptual one in that people tend to notice minor variations and sub-patterns more in columns. Patterns can also be accentuated by ordering the rows and columns of a table by some measure of the sizes of the figures (e.g. their averages). Ehrenberg reported that this can help to reveal the patterns in the data. It means using the structure of the table to reveal the structure of the <u>data</u> rather than merely to reflect the structure of the row and column labels (which is usually already well known). Ehrenberg claimed that it probably does not matter in which direction the figures are ordered for columns. But for the

rows of a table, showing the larger numbers above the smaller helps because people are more used to doing mental subtraction that way. Sometimes, there are different possible orders of tables, depending on the measures of size chosen. However, some visible ordering is better than none. A problem can arise when there are many different tables with the same basic format where application of the rule would lead to different orders for different tables. Ehrenberg suggested that, in such cases, the same order should be used in every table. As another means of improving the readability of a table, Ehrenberg recommended that figures that are meant to be compared should be placed close together. Single spacing is particularly effective in making the eye read down columns. There should however be occasional gaps between rows to help guide the eye across the table. Ehrenberg suggests between every five or so rows. It would also be reasonable to separate rows into meaningful groups, such as quarters in monthly figures. Ruled vertical and horizontal lines are useful around the borders of tables and to separate captions and labels from figures. However, lines between columns and rows of data do not bring particular benefits so long as the spacing is sensible. Colour can also be used to differentiate column and row labels from cell entries. Ehrenberg also recommended the common practice of aligning figures so that the same units lie on a vertical line (e.g. thousands, or the decimal point).

Finally, tabular formats which involve the user in remembering the outcome of one decision or search while carrying out a subsequent decision are difficult for some members of the general public to use (Wright and Fox, 1972). The most common way to structure a look-up table is to use two or more dimensions (sides to the table) as a way of cross-classifying the data. However, this is not the best way to structure such a table. Memory factors are important when using a rows x columns table. The outcome of searching for the appropriate column must be remembered while searching for the appropriate row. One way of reducing such problems is to arrange the headings so they are all along the same spatial dimension (e.g. all vertically arranged as column headings). Obviously this is not a practicable solution for all tables. Nevertheless people have been shown to make fewer errors when looking up items on tables arranged this way (Wright, 1977).

When table headings are arranged on one dimension they become analogous to a logic tree format, with the questions being implicit rather than explicit. Wright and Reid (1973) have shown that the decision structure imposed by such algorithms is advantageous when people are solving problems that have irrelevant information in addition to the necessary details.

3.7 Text on VDUs

3.7.1 Introduction

A useful review of this subject is available in van Nes (1986), which also contains a number of guidelines supported by research. The aspects examined here apply mostly to multicolour text displays and, to a certain extent, may also be generalised to the use of graphics.

3.7.2 The reading process and legibility

Bouma (1980) distinguished two processes in reading: searching for the desired information and perceiving (i.e. reading) the information. In print, sufficient attraction to headlines, etc. may already be provided by different type faces or italics. Such means are not usually available on current VDUs. Techniques such as displaying the relevant parts of a text in a different colour may be too conspicuous. Stewart (1976) and many others have observed that flashing, highlighted sections on a VDU can be used to draw attention to particularly urgent or important information (typically 2 to 4 Hz on-off cycle). Stewart pointed out that this is extremely "attention-attracting" and can therefore be too obtrusive and disruptive to the user. The reader's attention may be involuntarily and continuously distracted towards these areas. Reading itself may consequently be disturbed. Stewart further claimed (without reference to any documented evidence) that the flashing or blinking of complete screens can lead to complaints of headache, especially at frequencies of 5 to 15 Hz. Ramsey and Atwood (1979) speculated that the optimum blink rate is 3 to 4 Hz but could find no research on the optimal on-off cycle.

During normal reading of text, letter recognition and word contour both contribute to word recognition (Bouwhuis, 1979). For this reason, text is less legible in upper case than lower case: the ascenders and descenders in lower case contribute a characteristic shape to many words (van Nes, 1986).

Legibility is also affected by other parameters such as luminous contrast and line spacing. While reading, the eye makes a series of movements (saccades) to fixation points along the text line. The most frequent backward saccade is from the end of a text line to the beginning of the next one, but they also occur within a line. The saccade to the beginning of a line may be slightly misdirected if the required angle between this saccade and the text lines is small, with the result that a wrong line may be subsequently read. According to Bouma (1980) the minimum ratio between line distance (d) and line length (L) should be 1:30 or 0.033, corresponding to an eye movement back-jump angle of 2°.

3.7.3 Line length and spacing

Reading from one text page to another on a VDU is usually more complicated and slower than turning real pages of paper, which makes it more difficult for the reader to integrate information from two or more successive pages (van Nes, 1986). Also the text-carrying capacity of VDU screens is often comparatively rather limited. These two reasons may induce a writer to fill a VDU screen as much as possible to make use of the available space. However, the usual spacing of text lines is rather small, leading to inter-line interference effects and, in combination with the relatively long text lines, to small eye back-jump angles. For example, a typical VDU, single spaced, gives a d:L ratio of 0.035, which is very close to the minimum recommended by Bouma (1980).

Another problem arises when the word spacing comes close to the line-spacing: the inter-word spaces, especially when preceded by a punctuation mark, tend to join to more or less vertical 'rivers' of space between the seemingly scattered words of the text. This makes it

more difficult for the eyes to follow the lines. Double line-spacing gives higher legibility by inreasing the back-jump angle but makes less use of available space. An alternative suggested by van Nes (1986) is to present the text in more than one column, thus increasing the back-jump angle without the space penalty of double-line spacing.

3.7.4 Spatial grouping of text parts

With text printed on paper, pages with plenty of open spaces around and between the text are judged as 'easier' and 'more interesting' to read than pages wholly filled with text (Smith and McCombs, 1971). This subjective impression may be the result of objectively reduced legibility on a densely packed page. VDUs often have restricted legibility due to lack of sharpness of characters, reduced luminance contrast, veiling reflections, etc. so the insertion of space on a page is probably even more important as a means of increasing people's willingness to read it (van Nes, 1986).

3.7.5 General aspects of the legibility of coloured text

Colour contrast: The ease of reading a coloured text depends mainly on the luminous contrast between the letters and the background. Colour contrast plays a very subordinate part (Bruce and Foster, 1982). For a monochrome display, the colour of the phosphor has little if any effect on legibility if the luminances of the phosphors being compared are held constant (Radl, 1980).

This has important consequences for systems that do not compensate for the differences in luminous efficiency between red, blue and green phosphors. On such systems the luminosity and brightness order from high to low is: white, yellow, cyan, green, magenta, red, blue. Van Nes (1986) recommended that, with a 'black' background, the first four colours are best suited for rendering text. On a light (bright) background, e.g. white, yellow or cyan, the letter colour should be dark, e.g. black, blue, red or magenta in order to provide sufficient luminance contrast.

Dark text on a light background is generally more legible. However, on displays with a 50 or 60 Hz refresh rate, high luminance backgrounds sometimes show an annoying flicker effect, especially when large areas are involved. This is because the fusion frequency (the frequency at which a flashing stimulus appears to become continuous) rises with increasing stimulus area (Weale, 1978). More recently, one author, without quoting experimental evidence, has recommended a refresh rate of at least 70 Hz if a light background is to be used (van Nes, 1986).

Colours to avoid: It is important to provide sufficient luminance contrast to allow for those people with defective colour vision. Doing this will ensure that, when combinations of colours are selected that such people find hard to distinguish, such as red letters on a green background, the luminance contrast will still allow the text to be differentiated from the background.

Magenta should generally be avoided, since it is composed of colours at opposite ends of the spectrum, which cannot be focussed simultaneously because of the wavelength separation. Van Nes (1986) points out that this may be worse for wearers of spectacles because of the additional chromatic aberration of the glass.

Red letters on blue or blue letters on red can give a subjective impression of depth called colour stereoscopy. This effect may be used to attract attention on displays and advertising but it is not recommended for ordinary text (van Nes, 1986). Some combinations of red and green may also produce this effect in certain circumstances (Walraven, 1985).

3.7.6 Specific relations between reading and colour

People have a strong tendency to interpret identically coloured parts of a text or figure as belonging together. This association mechanism only works well when not more than three or four colours are presented on a page (Reynolds, 1979). This effect may cause confusion if in fact there is no relation between texts of the same colour.

Parts of text or figures that are coloured differently from their surroundings have objectively measurable increased conspicuity (Engel, 1980), the degree of which depends partly on the colour combination. A coloured part will involuntarily attract the eye when it scans the page. Colour differences can therefore be used as efficient search aids.

The colour of text may be used to attach meaning that is not necessarily conveyed by its content. To a certain extent the attachment of meaning to colours will have already been acquired from previous experience. Colour-coding can only be fully effective when the meanings are used consistently throughout the whole of the application. Subjective effects on the viewer of single or multiple colour displays, such as whether those colours are considered aesthetically pleasing or not, probably do not directly influence performance (van Nes, 1986).

3.7.7 Typographic effects

Typographic coding in print is used mainly for two purposes: to indicate headings, and to accentuate. On VDUs, several typographic means are commonly available, such as the use of double height characters, capitals and graphics characters.

The use of capitals in running text is discouraged for two reasons:

(a) The contours of capitalised words are less instantly recognisable, which impairs word recognition (Bouwhuis, 1979), even in headlines (Poulton, 1967).

(b) The space between two text lines in capitals is relatively small, which leads to blocks of text that look dense and uninviting to read.

On the other hand, capitals can be used to distinguish parts of a page and are also useful for indicating new paragraphs (van Nes, 1986). Double height characters are also useful to add emphasis and aid readers with reduced visual acuity. Graphics character fonts are attention-gaining because of their size and unusual shape, but are usually less

legible than normal fonts. Therefore their acceptability and discriminability need to be investigated before use (Bouma and Leopold, 1969).

3.7.8 Controlling text viewed

Scrolling vs windowing: When the portion of text is larger than that which fits on the screen at one time, it is necessary to have some form of scrolling or windowing function that allows the user to control the movement backwards and forwards within the text. One way of conceptualising scrolling is to visualise the text as if it moves or "scrolls" behind the stationary screen. A scroll down would reveal information beyond the upper limit of the screen. Alternatively, one could visualise the display screen as a movable window through which the stationary text is viewed. In this case, to display text beyond the upper limit of the screen one would use a "window up" command or up arrow key.

Experimental work (Bury et al, 1982) has shown that treating the screen as a window is the most natural for users, and produces fewer selection errors. The same principle should be applied if there is a need to move left or right over the text.

Paging vs. scrolling: A further choice concerns whether it is better to divide text into pages, akin to a book, or to scroll over the text, whatever its size. With scrolling, the information moves either continuously or line-by-line up the screen. With paging, the presented information changes all at once. It is usually assumed that scrolling is better suited to pieces of information lying relatively close together and that paging is superior for pieces of information lying far apart. However, the limited evidence available does not support this assumption. Schwarz et al (1983) compared scrolling and paging on three tasks: word reading, line searching and sorting. There was no clear advantage for either method in any of the tasks, using 20 naive subjects, in terms of completion time or errors although the statistical analysis of the experiment was seriously flawed. However, the experiment did reliably show that paging was preferred for reading of

continuous text. On the basis of the evidence available, then, paging is the method preferred by users, even though it may not actually improve task performance, at least for reading such as error logs or text files.

3.8 Printed Text

3.8.1 Introduction

In addition to text on screens, printed text in the form of user manuals etc. are an inseparable part of many systems. Consequently, it was considered desirable to include guidance on printed text as part of the ergonomic guidelines. This section concentrates on work from psychological, linguistic and ergonomic literature that has a clear message for the design of text. These different perspectives may not yet be able to provide precise prescriptions for structuring text, but they do identify several important factors. It does not include a review of standard works on the use of English.

As a general principle, text should be laid out to facilitate the acquisition of new information by drawing attention to important areas and limiting demands on the reader (Jonassen, 1982). First of all, a writer should try to develop a clear conception of the audience for which the text is intended. Hirsch (1977), in particular, emphasised the importance of tailoring writing to the requirements of a particular audience. This effort, Jonassen (1982) suggested, should provide a picture of the audience's prior experience with similar texts and thus what their expectations are likely to be. Also it gives insight into the amount of knowledge readers already possess about the topic of the text. This guides decisions on what to omit and include, and how to structure the text so that excessive processing demands are not made.

3.8.2 Titles, summaries, headings and advance organizers

There are a number of ways of asking readers to do things **before** they start to read which help their understanding of what is to follow. Titles, summaries, headings and advance organizers are examples of such

strategies (Hartley and Burnhill, 1977a). A clear concise title at the beginning of an article orientates the reader and helps with subsequent recall (Dooling and Lachman, 1971). Similarly, Hartley (1980) claimed that summaries are useful both before and after the text. Summaries before the text inform the users about the content - so they can decide whether to read it and find out what the text is about. Summaries after the text help recall and understanding of the text by presenting the main points and conclusions. Within the text, headings can be used to label parts of the text so that users know where they are and where they are going. They help with scanning, selection and retrieval as well as comprehension. Headings and subheadings, together with the systematic use of space, convey more readily the structure of complex text (Hartley and Burnhill, 1976). Such headings can either be placed in the margin or with the text. Headings in the margin may help more with scanning and searching. There is also some evidence (Robinson, 1961) that headings written in the form of questions may help the understanding of a young or less able reader (if the text answers the questions).

One alternative approach is that of advance organizers. These indicate ways in which new material is the same as, or different from, what the user has already read. They give material immediately before a text passage that is introductory, more general and more abstract than the following text. The concept of advance organizers was developed in educational research in the sixties and seventies. Their definition and use is described extensively in Jonassen (1982). They perform a similar function to headings, but they may contain more text (usually 10 to 15% of the text passage) and they can be shown in a different way typographically, for instance, by using a large margin devoted solely to advance organizers. They provide a conceptual framework that helps clarify the task ahead, and improve the memory and attitudes of the reader.

3.8.3 Indexing systems

For ordinary running prose, page numbers and chapters are adequate (Hartley, 1980). However, for reference purposes numbering or indexing systems are especially valuable. Where it is necessary for text to be

rapidly accessed, tables of contents, indices and tabs can be used (Bailey (1982). A British Standards document (BSI, 1976) gives probably the clearest specification available for the overall design of indices. Work by Burnhill et al (1977) has confirmed experimentally that the BSI recommended layout is at least as good as some other common methods.

3.8.4 Prose structure

Hartley and Burnhill (1977b) advised the use of short, familiar words rather than technical terms that mean the same thing. Wright and Barnard (1975) cited examples of words used in government forms such as 'gainful occupation' and 'mixed hereditaments'.

Long sentences are usually accepted to be more difficult to understand (e.g. Hartley and Burnhill, 1977b, Davies, 1972), partly because of the extra memory load they place on the reader. The greater the number of subordinate pieces they contain the more difficult they are to understand (Miller, 1964, Wright and Barnard, 1975). Hartley and Burnhill (1977b) suggested that few should have more than one subordinate clause. Hartley (1980) advised that, as a rule of thumb, sentences less than 20 words long are usually fine. Sentences 20 to 30 words long are probably satisfactory, 30 to 40 words is suspect and sentences containing over 40 words benefit from rewriting.

There is a distinction between 'given and 'new' information in the course of reading text. 'Given' information has already been mentioned in a preceding portion of the text, while other ideas in a sentence are new since they are being introduced without prior mention. Generally, the subject of the sentence (usually the first thing mentioned) should reflect given information. When it does, it serves the function of tying the ideas in a passage across sentence boundaries.

As a general rule, a simple affirmative sentence is easiest to understand. Introducing the passive form or negatives creates problems, either slowing the reader down or causing errors (Broadbent, 1977). It may also cause memory faults: a sentence in the negative or passive form may be remembered in the active form, even though this may change

the meaning (Harris, 1976). Exceptionally, if the reader is likely to make an assumption, then one may sometimes use a negative construction to deny it (Broadbent, 1977).

Many sentences can turn out to be ambiguous, often because the writer's implicit understanding has not been conveyed to the reader, thus allowing an interpretation that the writer had been prevented from seeing because of implicit extra knowledge. Many authors advise testing the material on the target audience to trap this sort of error. Ambiguities and difficulties can also arise from the use of abbreviations and acronyms. Obviously, their meaning should be explained to the reader, at least on their first occurrence.

One author (Bailey, 1982) suggested that paragraphs should contain 70 to 200 words and should deal with a single logically presented idea, since shorter paragraphs tend to facilitate comprehension. The theme of each paragraph or section should be stated clearly at the beginning in order to focus the reader's attention on the main point being developed. The overall organization of paragraphs within longer stretches of text should reflect judgements about the relative importance of ideas being presented with major concepts not being buried in a mass of detail.

Finally, both Hartley (1980) and Poulton (1970) strongly advised against the use of footnotes in text. As well as being a nuisance to type and print, footnotes are an irresistible interruption to the reader. They break concentration and the flow of information from one sentence to the next. Both authors suggested that excess material should be placed in an Appendix - although it may not then be read.

3.8.5 Readability

There are many readability formulae that attempt to quantify and predict the difficulty of reading text. These are generally formulated to give an American reading grade level (1 - 12) or an index from 0 to 100. A comprehensive review of these indices is given in Klare (1974). Some of these formulae can provide reasonable indices of difficulty but they do not indicate causes of difficulty or say how to write readably. Often

there are inconsistencies between different formulae on the same text, but one that has had limited validation on technical material is called the Automated Readability Index (Smith and Kincaid, 1970):

$$ARI = (w/s) + 9(l/w)$$

where:

ARI = Automated Readability Index
w/s = words per sentence
l/w = letters per word

This gives a scale of approximately 0 (easy) to 100 (hard).

Such formulae are obviously not an infallible guide to the readability of text: some short sentences are difficult to understand and some long words are easy to read because of their familiarity. Nonetheless, Smith and Kincaid showed advantages for more readable text for several types of document, including textbooks, scientific papers and job aids.

3.9 Abbreviations

3.9.1 Introduction

Several ways have been suggested to construct good abbreviations for use with computer systems. A recent review of experimental data on the use of abbreviations with computer systems was given in Ehrenreich (1985).

Ehrenreich (1985) considered that abbreviations in this context can serve two purposes. One is to speed data or command entry. By encoding messages, that is, by translating words into abbreviations, the amount of time spent in keyboard entry can be reduced. Conversely, abbreviations may be used to reduce the space needed to display messages, options or captions to data. This requires the user to decode, that is, translate the abbreviations back into words.

3.9.2 Construction of abbreviations

The most frequently used abbreviations are ones that are produced without recourse to a rule. Usually, a system's designers rely on intuition to create abbreviations. An investigation of people's natural abbreviation behaviour was undertaken by Hodge and Pennington (1973), who asked participants to generate what they thought were good abbreviations. The experimenters also tested how well people could decode abbreviations produced by others.

Their study supported the following conclusions:

(a) People favour contraction when abbreviating short, uncommon words, and they favour truncation when abbreviating long, common words.

(b) There is little consistency between individuals in the abbreviations they create for a word.

(c) People are fairly good at decoding a naturally produced abbreviation if it is the most common choice for encoding.

Streeter et al (1983) assumed that naturally produced abbreviations were a product of a natural cognitive strategy, and attempted to discover the characteristics of this strategy. On average, the most common abbreviation for a term was produced by only 37% of the subjects. From these most common abbreviations, Streeter distilled the following abbreviation rules which are also consistent with the findings of Hodge and Pennington (1973):

(a) For monosyllabic rules, delete vowels.
(b) For polysyllabic rules, retain the first few letters (truncation).
(c) For multi-word terms, retain the first letter of each word.

The researchers then studied how easy it was to remember naturally produced abbreviations compared with rule-generated abbreviations. Participants working with rule-generated abbreviations correctly produced the full meaning of 70% of the abbreviations, whereas

participants working with naturally produced abreviations recalled only 54%. The factor of internal consistency (i.e. rule-governed structure) seemed to play a more important role than naturalness.

Ehrenreich (1985) reviewed a number of alternatives for formal abbreviation rules that have been studied empirically. He concluded that:

(a) Naturally produced abbreviations are generally inferior to rule-based abbreviations for encoding

(b) In all encoding tests using truncation, these abbreviations have been found to be at least as good as or better than other abbreviations

(c) Encoding performance on rule-generated abbreviations can be enhanced by using a simple rule and teaching that rule to the user. No similar advantage has been found for decoding performance.

Of the available rules, truncation is the simplest. It is obvious in every case how to apply the rule, once the user knows it. Even if the user is not explicitly taught the rule, but learns it through repeated use of the system, a truncation rule is more quickly learnt.

3.9.3 Ambiguity

The truncation rule used on its own may occasionally produce the same abbreviation for more than one word. This raises the question as to whether the truncation rule, despite its documented ease of use, is practical.

Ehrenreich estimated experimentally that non-unique abbreviations would be produced about 10% of the time with four-letter abbreviations. He argued that this does not undermine the usefulness of the technique if the following points are taken into account:

(a) If two commands have an identical abbreviation but can never occur

in the same context, then context is sufficient to remove the ambiguity. There is no reason to believe that users will have difficulty with such abbreviations.

(b) Another possibility is to interrogate the user when an ambiguous command is entered. This is not the optimal solution because it increases command entry time and may be impractical in some situations.

(c) One of the words being abbreviated may be changed if point (a) is not sufficient.

(d) If none of the above points work then it may be necessary to generate abbreviations that violate the truncation rule (Moses and Ehrenreich, 1981). However, given the literature on the improved recall of a single distinctive item embedded in a serial list (the von Restorff effect) one might expect a small number of such deviant abbreviations to be remembered because of their uniqueness.

Streeter et al suggested that the lengths of the truncated abbreviations should be the minimum to achieve uniqueness. The user should be told the minimum number of letters to distinguish all command names, and also told that fewer letters will often suffice.

4. SURVEY OF MSS USERS

4.1 Introduction

The previous section provided a review of the ergonomic literature relating to the design of information systems, with special reference to those aspects relevant to MSS (MIDAS Surface Software). From this literature review a set of general applied guidelines was produced (Appendix A). However, it was felt that not enough was known about the information requirements of actual users at collieries. Without this contextual information, it was not possible to follow the goals of the prescribed guidelines completely, namely to adapt the presentation of information to the task requirements of the users. Therefore a structured interview pro-forma was developed to provide this information.

4.2 Aims

The main aims of the interviews were:

(a) to analyse the task and information requirements of MSS users;

(b) to determine the most frequent and important tasks performed with the MSS to obtain the required information.

Additional objectives were:

(a) to give an indication of the level and type of experience of the user groups;

(b) to identify the potential benefits from improved task performance with MSS;

(c) to gather opinion and comment on the usability and provision of information by MSS;

(d) to examine the match between design objectives (and beliefs about the system's usefulness) with actual use.

In general, the intention was to provide the information whereby the information presentation and selection methods could be adapted to the requirements of users. To support this general aim, interviews were conducted with Headquarters development staff and Area support staff as well as colliery users.

A further objective was to gather opinions and ratings of usefulness of the MSS system, both from current users at collieries and from development and support staff. This was to allow expected and actual use of the system to be compared.

4.3 Method

For task and information requirements analysis, a questionnaire was developed (Appendix B). This was designed to identify the general information-providing tasks performed with the MSS system and to break down the tasks carried out from general descriptions to detailed specifications of the task information requirements and associated displays. Alongside the delineation of the task structure for each interviewee, comments, opinions and reported problems with the current MSS system were collected.

Interviews were conducted with HQTD software development and field support staff (four interviewees), systems support staff in one Area (two interviewees), and at six collieries in two Areas (21 interviewees). Abbreviated names for locations are used for ease of reference in subsequent analysis and comment, as shown below.

DEV	software development and field support staff at HQTD
SUP	Area Systems Support Engineers
A to F	Collieries

Colliery interviewees were selected on the basis that they were actual users of the MSS system. At colliery level, it was the intention to interview a control room operator, and representatives of the electrical engineering, mechanical engineering and management functions. However, if any of these functions at a colliery did not make significant use directly or indirectly of the MSS system then an interview was not conducted. Due to time constraints, it was not possible to interview every person who had at any time made use of MSS at every colliery. Nevertheless, a particular effort was made to interview all the major users at each colliery studied. Where this was not possible it is noted in the presentation of results (section 4.4) below.

Following a task description and interview, interviewees were asked to rate the importance of the MSS system and its contribution in a number of areas. The full questionnaire and rating scales are shown in Appendix B.

Ratings were collected for the MSS system as a whole, and for each reported task individually. For both, the respondent was asked to rate on separate scales the usefulness of MSS in five areas: safety, production, industrial relations (e.g. use of data to determine bonuses or effects on incentive schemes), maintenance and long term planning. For the overall assessment, a seven-point scale was used. For the assessment of individual tasks responses were coded in five categories. Analysis of ratings of the overall MSS system are given in section 4.4.5. Ratings for individual tasks are given under their respective headings (sections 4.4.1 to 4.4.4).

Respondents were requested to rate the usefulness of the MSS system independently of the perceived or actual benefits of MIDAS-controlled steering. Nevertheless it was difficult for interviewees in practice to isolate their attitudes to the two systems. It is likely that some of the ratings are influenced by the undoubted benefits of MIDAS steering. It should be noted that the ratings were not devised as any kind of psychological instrument, but only to give a practical indication of the impact of MSS and its benefits as perceived by HQTD and colliery staff.

4.4 Results and Discussion

In general there was a high degree of commonality in the main or core tasks performed and the displays used to support them as reported by colliery staff. (Comparisons with development and support staff are discussed in section 4.4.5.) The most central tasks were monitoring current shearer performance and face management. Other tasks were performed more irregularly or infrequently, and not consistently by the same personnel across collieries. These included monitoring steering performance, checking for transducer or data transmission errors, fault diagnosis and engineering monitoring. The results and discussion for each main task are shown in the subsections following.

Some, but not all, of the interview material related closely to the task structure being discussed. Many comments or discussions outside the formal structure of the interview were recorded. Since these are often a rich source of information, representative examples are given in the analysis and discussion below. Some comments compare the present system with its experimental predecessor, "System 70,000".

Ratings were collected from 15 interviewees. Four of the respondents were from HQTD, the remainder from Area and collieries. Ratings were not collected on two occasions at one colliery (B) because MSS and MIDAS had been removed several months before.

It has not been possible to do a straightforward compilation of ratings for one task (engineering fault diagnosis/monitoring), because of the freedom allowed the interviewees in describing their tasks. The contents and means of achieving this task varied greatly, because of personal idiosyncracies, degrees of familiarity with the system, and varying stages of development of the software at successive interviews. It would not be accurate or fair to the system developers to present ratings of usefulness of the system for achieving the same task by widely divergent means. Instead, the text tries to convey the advantages and disadvantages of the varying methods used to support this task at each colliery (section 4.4.4). It has been possible to compile

ratings for tasks which had similar characteristics and contents across all collieries: face management, monitoring current shearer performance and checking steering performance.

4.4.1 Face management

Description: The task of face management was supported by the routine production of information at the end of every shift (also some for each shear) in the form of plots or listings. (Unless otherwise stated, plots and listings should be assumed to be produced on paper.) These were used by management to monitor the coal production quality and quantity from the MIDAS face and to monitor face conditions for production and safety purposes. Table 1 shows the information components of the face management task. The task was one of retrospective analysis. Results from each shift, and some details related to each shear, were examined on a regular periodic basis, usually daily, by the management and other key personnel, such as the electrical engineer. Nearly all the plots related to data collected for a complete shift. The face profile was typically plotted for each strip within the shift. A discussion of each of the displays associated with this task are given in sections 4.4.1.1 to 4.4.1.5 below.

TABLE 1. Task Information Components of Face Management

Task	Associated Displays	Abstracted information
face management	face profile	Mean roof coal left Roof control quality Floor pass quality
	machine travel	% time in auto Number of shears
	time statistics pie	% time in auto Delays above criterion Delays below criterion
	tonnage pie	Total tonnage cut Coal left
	delays	Major delays and reasons

The data for this task were usually taken from the MSS system by the control room operator, although other personnel such as an electrical engineer or shift charge engineer would occasionally extract the data if the CRO (control room operator) was occupied with other tasks.

This overall task of face management was performed in some form at all collieries studied. Some collieries had a version of the software that included the capability to plot chosen graphs automatically at the end of every shift. Where the software only allowed manual plots, the control room operator sometimes did the face profile plots and engineering plots of sensor readings vs face position at the end of every strip to avoid a backlog building up. (Face profiles were plotted for each strip.) The use that was made of the task information components at each colliery visited is shown in Table 2.

TABLE 2. Use of Face Management Task Information Components at Collieries[1]

Information Component	Pit
	A B C D E F
Face Profile plot	Y Y Y Y N Y
Machine Travel chart	Y Y Y Y Y Y
Time Statistics pie chart	- - - Y Y Y[2]
Tonnage analysis pie chart	- - - Y Y N
Delays listing	Y Y N N Y N

[1]At Colliery D, plots were produced automatically at the end of each shift. At other collieries they were initiated on operator instruction.

[2]At Colliery F, the time statistics pie chart was produced solely to be posted on a noticeboard to provide face staff with feedback on their performance.

Key: Y = Yes, N = No, - = Not available

Table 3 shows the ratings given by staff of the usefulness of MSS to face management, from A (greatly impaired) to E (greatly improved). C thus represents a neutral point.

TABLE 3. Ratings of the "Face Management" Task (n = 11)

	Rating A	B	C	D	E
Safety			2	9	
Production				4	7
I-R			4	7	
Maint			9	2	
LTP			8	3	

Broadly speaking, the facility to provide retrospective management plots, delay logs etc was rated as having no usefulness to maintenance or long-term planning, slightly improved effect on industrial relations and safety and a considerable effect on production.

4.4.1.1 Face profile

Description: A typical face profile plot is shown in Figure 5. At the head of the graph the shift and time to which the plot relates is displayed. The graph shows face position in metres against seam height in metres. Lines indicate the boundaries of floor, roof, roof coal left and extraction. The graph also presents figures in metres for mean roof coal, standard deviation and mean extraction to three decimal places. Of these, the one most attended to was the mean roof coal.

At all but one of the collieries studied, a face profile plot was produced for every strip cut. The plot was typically examined by an electrical engineer and management, mainly to monitor the roof and floor profiles and the amount of coal left on the roof. The amount of roof coal left is monitored for production reasons, since any extra roof coal that can be cut compared with manual shearer guidance in effect

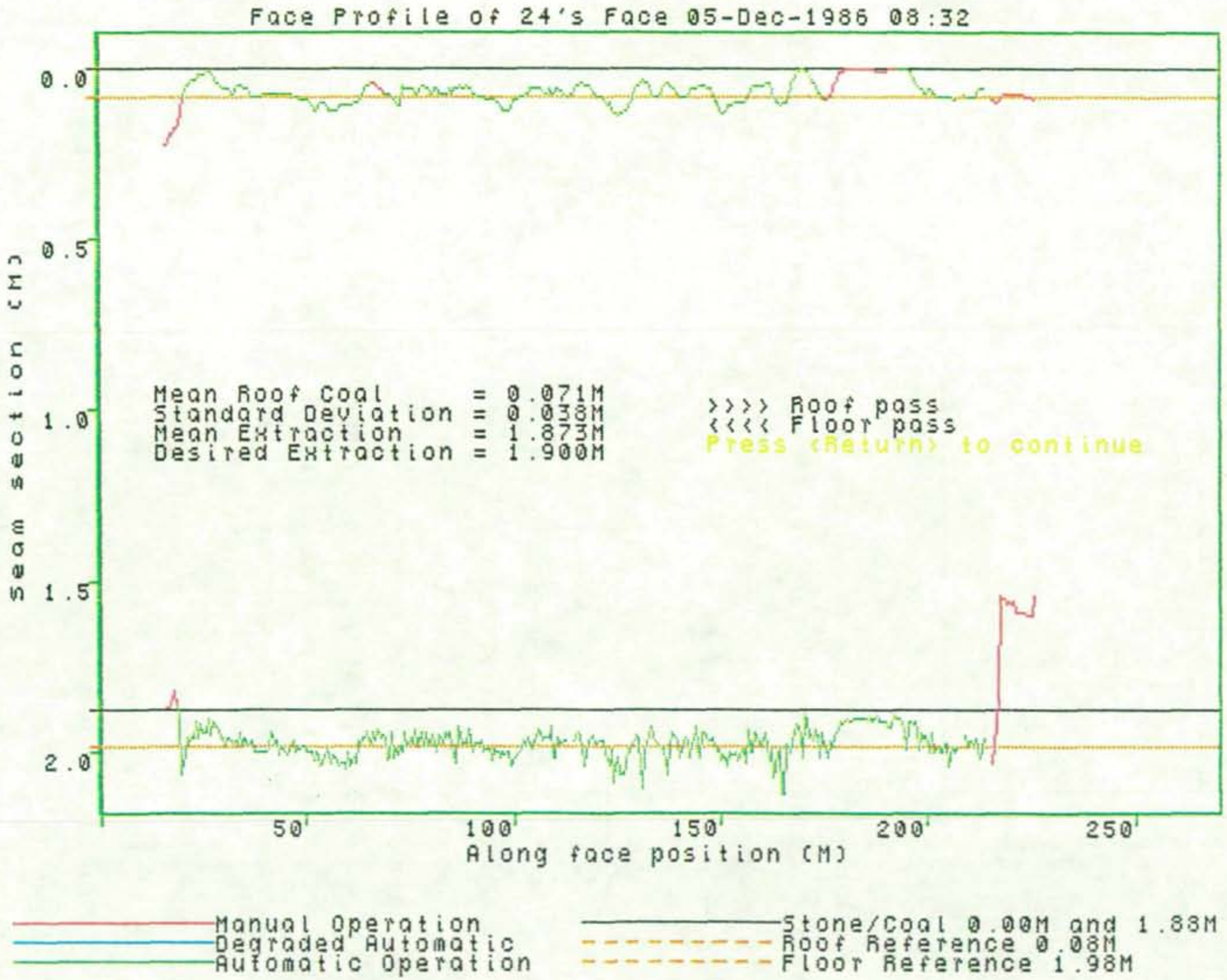

FIGURE 5. Typical Face Profile Plot

means increased coal production on the same yardage cut. It is also monitored so that potential problem regions along the face can be highlighted, and because an uneven roof can lead to an undesirable increase in requirements for timbering and possibly impaired safety. A small and consistent thickness of coal left on the roof leads to more stable roof conditions.

Comment: The mean extraction logically contains the same information as the mean roof coal left, which perhaps explains why it was not notably attended to. The standard deviation appeared to mean little or nothing to most interviewees. All of the figures are presented to more accuracy than is required, and in fact at least an order of magnitude more precisely than the system is capable of actually resolving.

Given the relative height to length of a coalface it is inevitable that the scale of the abscissa (X axis), showing the face length, is compressed much more than that of the ordinate, which shows seam thickness. An Area support engineer claimed that some users of the graph said this could be misleading to inexperienced eyes, because it has the effect of exaggerating any deviations from a flat floor and roof and smooth shearing.

One colliery (E) did not use the plot because attempts to produce it resulted in a software error. On being shown a copy of a typical face profile for the first time, the CRO and electrical engineer could not see a need for it because essentially the same information was available from engineering plots which they routinely produced.

Typical comments from collieries: The time given at the head of the face profile does not always clearly relate to the machine travel chart (section 4.4.1.2). In fact the time given is the first data point of the shear requested. It takes experience and time for people to be able to relate face profile plots from several shears to one shift's machine travel chart. Giving the start time of the plot on the face profile is not enough - it ought to say what shift it is related to, especially if a shear had been started in a previous shift but largely completed in the next. The old system (System 70,000) gave both the shift name and

the cut number, which helped to make identification more certain. (A)

If a large amount of data is lost in transmission then the figures for mean roof coal extracted can appear obviously incorrect, presumably because the software has available only a small amount of data. Perhaps the figure should not be calculated in such circumstances, to avoid potentially misleading results. (F)

Colliery users need a facility to adjust the definitions of automatic control limits within the software because if it is set too far out during software configuration it can spuriously affect the percent auto and manual figures (F).

4.4.1.2 Machine travel

Description: At all the collieries studied, a machine travel graph was produced by the MSS system at the end of every shift for management use. This chart is traditionally produced manually in most British Coal collieries. A typical machine travel graph produced by MSS is shown in Figure 6. The position of the shearer is plotted on a graph of face position vs time. The graph shows the number of strips cut, the times spent in auto, manual and degraded auto steering (a form of auto steering when certain transducers are not functioning correctly), machine run-time, percent in auto steering, the times of commencement of the strips (by interpolation of the scale) and a visual indication of the time taken to do them by the slope of the plotted line. The ends of each plotted line also reveal the activities at the face end.

The main actual use of this graph was to see the number of strips cut for that shift by counting the number of zig-zag lines representing the machine's travel along the face. This information has no more concise representation on the MSS system. The graph also gives other information that can be taken from other plotted output, such as an indication of the delays during each shift. This information is available in detail from the delays print-out.

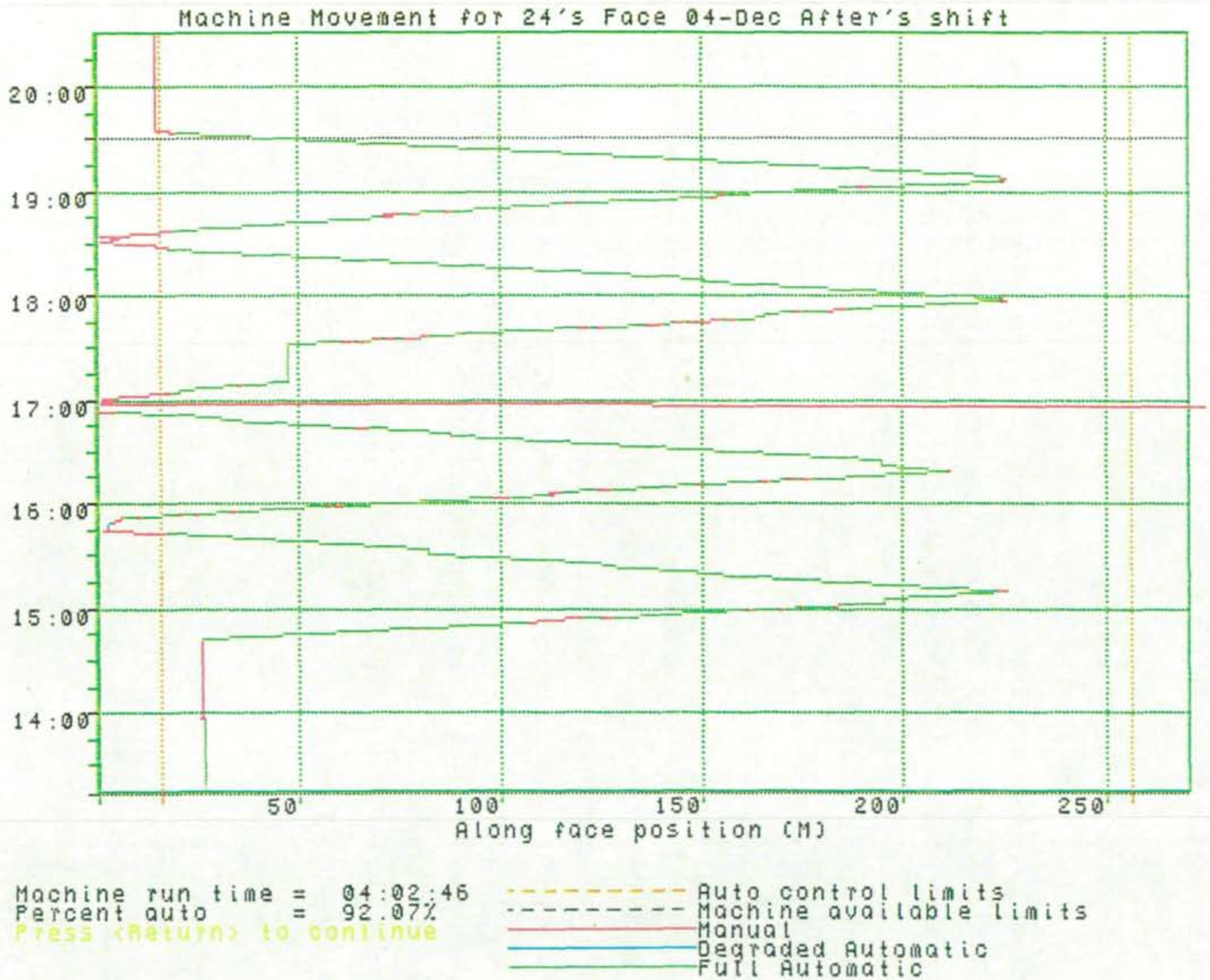

FIGURE 6. Typical Machine Travel Graph

Comment: The digital information on shearer run-time and percent auto is given to more accuracy than is necessary. An overall picture only is needed. There is an apparent discrepancy between, on the one hand the lengths of the plotted red and green lines to indicate auto or manual, and on the other, the percentages given digitally. This causes disputes over the accuracy of the data, which weakens the faith put in the machine utilisation pie chart.

One colliery engineering user (F) commented on the visual distinctiveness of the plotted lines representing automatic (green) versus manual (red) control of the shearer. The prominence of red was useful when leafing through a number of machine travel charts to spot occasions when the amount of manual steering was unduly high. He felt that this offered an improvement over the predecessor to MIDAS and MSS (System 70,000) on which colour was not used.

4.4.1.3 Time statistics pie

Description: The time statistics pie chart provides a breakdown of shearer activity per shift. A typical example is given in Figure 7. Each slice represents the number of minutes the MIDAS shearer's activity fell into a particular category. The categories are: steering in manual, steering in auto, steering in degraded auto, travel time (a pre-set constant), total duration of delays under a pre-set interval, and total duration of delays lasting longer than the pre-set interval. The total duration of the shift and the number of delays in each category are also printed.

Half of the sample of collieries (A, B, and C in Table 2) with earlier software versions did not have this option available. The remainder routinely produced the plot at the end of every shift. One colliery did not require this plot for management purposes, but produced it for display on a colliery noticeboard, as an incentive to maximise productive time (and therefore wages).

Collieries also collect delays information from several other sources,

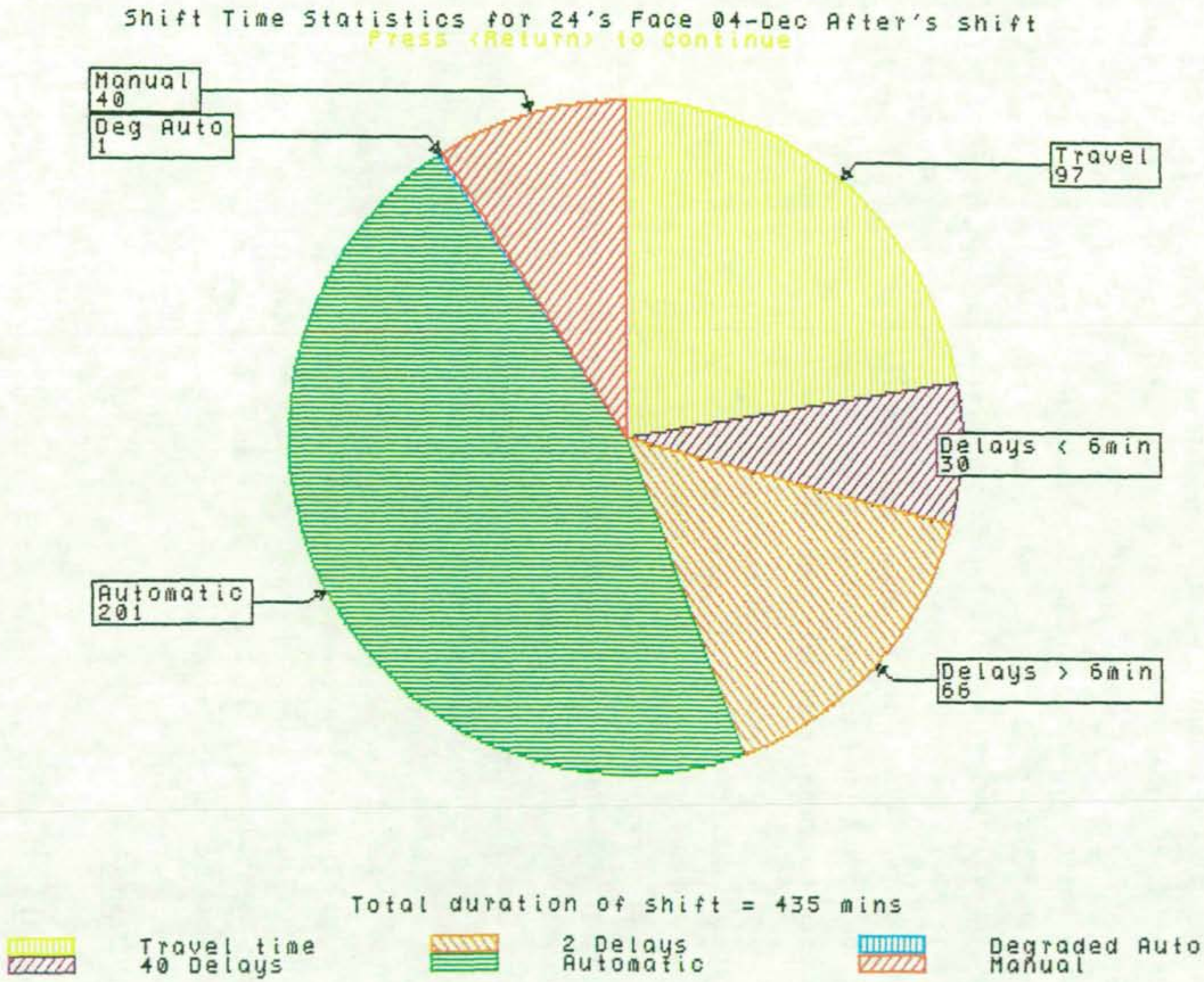

FIGURE 7. Typical Time Statistics Pie Chart

such as deputies and written control room logs. The time pie chart does not have any reasons for delays so it does not improve on the information already available. Hence some managers felt it was not particularly useful. Some managers commented that they would prefer the pie without travel time since this is known and is taken as a constant.

Comment: Difficulties arise when there are overlapping shifts. The MSS system does not allow a new shift to be defined as beginning whilst the defined end of a previous shift has not been reached. In practice, men for a shift may be travelling to a face whilst the men from the previous shift are returning to the surface. Since the MSS system defines travel time as part of the machine available time, it will not, in effect, allow the shearer to be defined as available to two shifts simultaneously. The tactic adopted by Area engineers in such cases is to set the travel time to zero in the system configuration. This circumvents the problem rather than cures it.

There are also difficulties in producing the time statistics pie chart if there is a delay in progress as the shift comes to an end. The chart cannot be produced until the delay has finished. Experienced control room operators produce all the other required hardcopy first so that a backlog whilst waiting to be able to plot the time statistics pie is avoided. Since turning off the shearer near the end of the shift counts as a delay, sometimes the chart cannot be produced until the shearer is turned on by the face men on the next shift. (This does not apply to any of the other plots.) At one colliery visited, this unfortunate "delay" caused by the shearer being turned off at the end of a shift occurred over a bank holiday weekend, so the time statistics pie chart could not be produced until the next week and the operator's updated display showed a current delay of over 8000 minutes!

4.4.1.4 Tonnage pie

Description: The tonnage analysis pie chart is presented in similar format to the time statistics pie chart. A typical example is shown in Figure 8. Each segment represents the tonnage produced in that category for the chosen shift. The categories are: floor dirt, coal, inseam

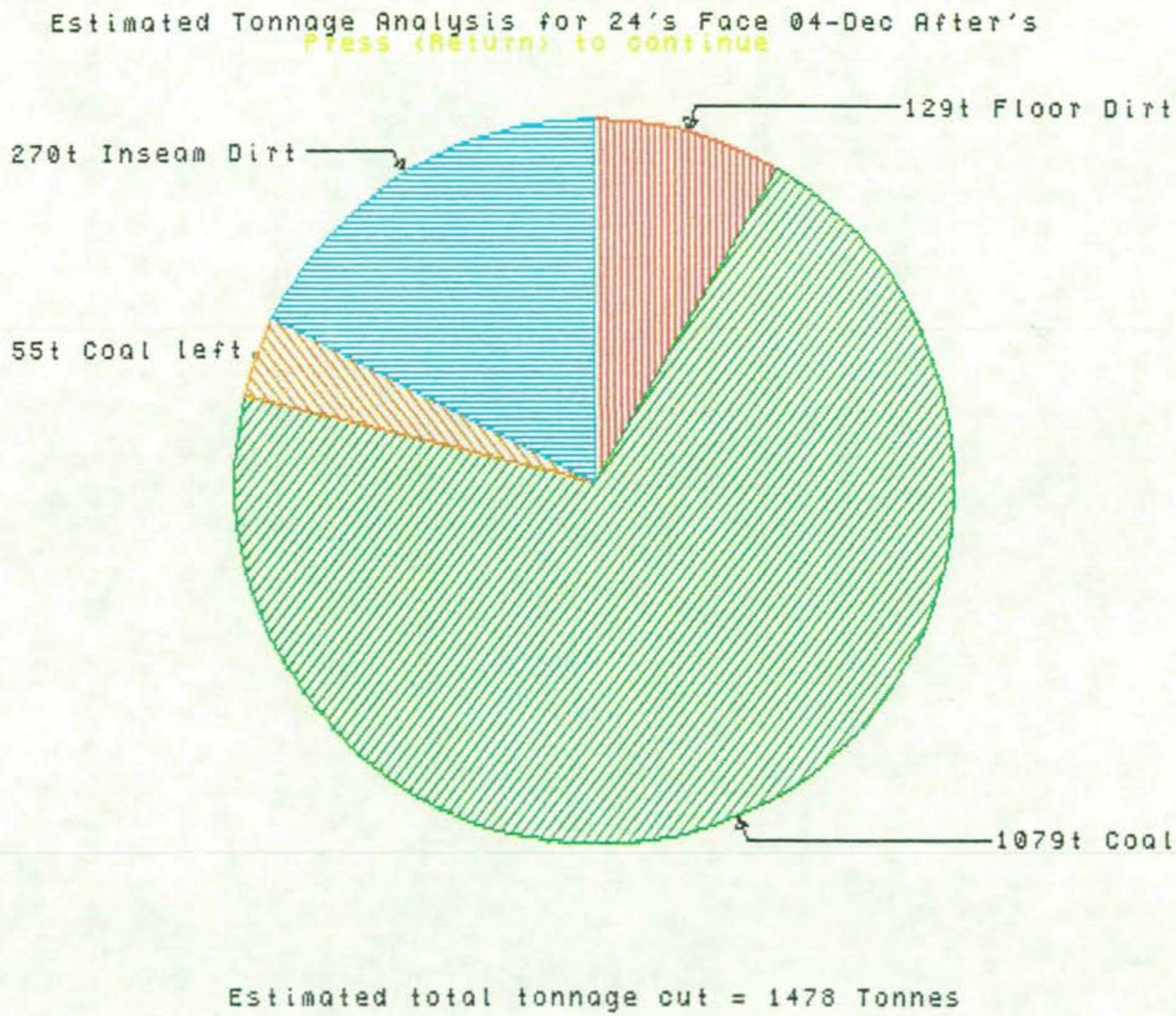

FIGURE 8. Typical Tonnage Analysis Pie Chart

dirt, and coal left on the roof. The estimated total tonnage cut for the shift is also printed. As with the time statistics pie chart, the tonnage pie chart was not available to three collieries. Of the remaining three, two routinely printed it at the end of every shift.

Comment: Earlier versions of the software did not point out that the tonnage analyses were estimates. The software does not know many of the elements it would need to calculate (as opposed to estimate) the tonnage produced. For instance, there are no transducers for the amount the shearer has advanced into the coal panel for each strip cut. Neither is the amount and thickness of dirt in the seam available to the software, except by a pre-set estimate.

Later versions point out on every tonnage pie chart printed that the figures are estimates. Nevertheless, managers lose faith in the chart when the estimates are widely different to calculations based on face surveys and regular measurements of advance. One engineer commented that if the results of face surveys and measurements of advance by deputies could be incorporated into the calculation, the results would be much more accurate.

4.4.1.5 Delays

Description: One of the common task information components of the face management task for control room operators was a listing of the delays during each shift. The task of actually producing this listing usually fell to the CRO. It was usually examined by management in relation to reasons for delays from other sources, such as deputies' reports, control room operator's log book etc. In some cases the delays listing was produced in addition to the time statistics pie chart. An example of the first page of a delays listing taken from a later version of the software is given in Figure 9.

```
          Delay summary for Day's Shift 21-May-1987 for 24's Face  Page 1
          ----------------------------------------------------------
Shift start time          06:00:00. Shift end time          13:15:00.
M/C available start time 06:45:00. M/C available end time   12:30:00.

Number of long and short delays                        40
Machine position at end of shift                       25.25 Metre.

Number of delays greater then 10 minutes               5
Total time of long delays including official breaks     1Hr.32Mns.33Scs.




Note: Delay summary only includes long delays within machine available limits.
This includes any official breaks.

Press <Back Space> for shift menu or <ESC> to exit :-
```

FIGURE 9. Example of delays summary

At F, the control room operator discontinued the production of a delays listing on his own initiative, without any complaints from management. He kept a separate record of delays in a log book, as was the system before MSS was introduced. This was sufficient for routine reporting and to answer telephone queries. At A, only the delays print-out was used. At C the delays list was not routinely produced. The system did not have the facility for producing pie charts.

Comment: A source of dissatisfaction was the fact that System 70,000 produced a delays print-out with a summary at the end, whereas early versions of MSS did not produce a summary, just a raw delays log. This was corrected in later versions.

The most frequent comment concerned the lack of reasons for delays on the MSS system. The system was compared with another face monitoring computer system (FIDO), where the reasons for delays were said to be entered on the computer by the control room operator. There was some debate as to whether it should be the function of MSS to provide such reasons, or whether another computer system (CIS, Colliery Information System) should in future provide this function. Whatever the system boundaries, this illustrates the need for the implementation of new technology to be considered in relation to colliery information

requirements.

4.4.2 Monitoring current machine performance

Description: The task of monitoring current shearer performance was carried out by the control room operator. A typical operator's display intended to support this task is given in Figure 10. For this task, "performance" is intended to mean the routine operation of the shearer, such as movement and steering status, rather than engineering performance. This task was in reality a subset of the CRO's task of being aware of the current status generally in the colliery. The information components of this task are shown in Table 4. The use of the task information components at each colliery are shown in Table 5.

TABLE 4. Task Information Components of Monitoring Machine Performance

Task	**Associated Displays**	**Abstracted information**
Monitor machine performance	Operator's updated display	m/c position, auto/manual, direction of travel, delay time
	Current steering data	Used as substitute source for above data

TABLE 5. Use of Machine Performance Monitoring Task Information Components at Collieries

Information Component	**Pit**					
	A	B	C	D	E	F
Operator's Updated Display	Y	Y	Y	Y	Y	Y
Current Steering Data	N	N	N	Y	N	N

Unlike the face management task, the shearer monitoring task was

*** MIDAS VERTICAL GUIDANCE SYSTEM ***
OPERATOR'S DISPLAY FOR S04's Tail M/C

TIME	16:21:07
MACHINE POSITION	84 METRE
MACHINE DIRECTION	TO THE TAILGATE
MACHINE STATUS	STANDING
MACHINE SPEED	0.00 METRES/MINUTE

CURRENT DELAY TIME NOT AVAILABLE

Press SPACE bar to clear displayed error. Press <ESC> to exit.

FIGURE 10. Typical Operator's Updated Display

performed by the control room operator continuously in "real time"; that is, the status and progress of the shearer were monitored as things actually happened, rather then in retrospect. The information to support the task was examined on screen, rather than on paper.

The main purpose of the task was to be able to answer queries on the current state of the shearer. Such queries tended to come from management or supervisory staff by telephone during normal shearer running. The queries usually took a simple form, such as "How many strips have been cut so far this shift?", "Is the shearer in auto or manual steering?", "What is the shearer's position on the face?" and "What direction is the shearer moving in?". These queries were fairly frequent. For instance, the management usually asked questions relating to production progress more than once an hour. The frequency of queries rose when problems occurred or there was known to be an ongoing difficult situation.

The operator also typically compiled information that was not supported by MSS, such as the number of strips cut and the reasons for stoppages, so that enquiries could be answered immediately.

Ratings for this task are shown in Table 6. The responses can be characterised as saying that monitoring of current shearer performance is perceived as slightly improving production, but having no effect on safety, maintenance, long-term planning and industrial relations.

TABLE 6. Ratings of the "Monitoring Current Machine Performance" Task (n = 10)

	Rating A	B	C	D	E
Safety			10		
Production				9	1
I-Relations			9	1	
Maintenance			10		
LTPlanning			10		

Comment: Because of the need to support queries occurring at unpredictable times but with largely predictable content it is important that the operator's on-line display provides all the necessary information immediately. For this reason, the usual display on the MSS VDU, in the absence of other requirements or tasks, was the "Operator's Updated Display".

In addition to the information abstracted from displays the operator keeps a record of the number of strips cut on the MIDAS and other faces. None of the current displays directly provide this information. Potentially, this information could be abstracted from the machine movement graph by counting the number of passes. This was not observed to happen, presumably because of the unacceptably long time needed to collect this information in response to a telephone enquiry. Instead, operators kept their own record with pencil and paper so that queries could be serviced without delay.

At some collieries, the digital display of face position on the operator's updated display was not in the units used at the colliery (i.e. position can be shown in metres or by chock number). Sometimes, the size of the chocks allowed an easy mental conversion into the units preferred by a telephone enquirer. At one colliery a conversion chart had been drawn up by the operator and fixed next to the MSS display. Some personnel expressed the opinion that MSS should display the position in both metres and chock number, since personnel making telephone queries could have differing preferences for units.

An operator at one colliery (D) sometimes used the current steering data tabular display to display essentially the same information as the operator's updated display. This option was sometimes chosen when returning from displaying other information or initiating a plot of data. The operator felt that the time required for the display to appear was shorter for the steering data option than for the operator's updated display. It should be noted that this colliery's MIDAS system supported two MIDAS shearers and two displays with one computer. Therefore the response delays were significantly longer than at other collieries.

The hardware controlling the system "handshake" was usually placed alongside the operator's display. This is a small unit which provides the interface between the communication lines from the underground MIDAS system and the surface computer. The "handshake healthy" light functions as a display telling the operator quickly that the steering system is running. Sometimes the handshake is lost for a few seconds or longer. When this happens, the operator's updated display does not retain the status of the shearer as last known. It was suggested that it would be helpful if it were to do so, with a message indicating the problem. One CRO (at E) said that if the handshake is temporarily lost he thinks that the machine has stopped, so he telephones the face, only to find that the shearer is running normally. He thought there was a delay of perhaps 20 seconds before a restored handshake registered on the MSS display.

4.4.3 Checking steering performance

Description: The information components of this task are shown in Table 7. This task divides into retrospective analysis of steering performance by shift, using plots, and real-time examination of steering performance using the "current data" option (on older software) or "steering data options" (on newer versions). The use of these information components at collieries is shown in Tables 8 and 9.

Checking steering performance is a third main category of task. This classification refers to the routine examination of steering performance data. Examination of steering data on specific occasions when it is known there is a fault are treated under a different heading (section 4.4.4 below).

In producing steering performance plots for retrospective examination, the tendency was for the operator to produce them along with management plots (or include them in the automatic end of shift plots if the software supported this). Where plots were manually requested, the engineering plots would sometimes be produced by the electrical engineer if the CRO was busy.

TABLE 7. Task Information Components of Checking Steering Performance

Task	Associated Displays	Abstracted information
Checking steering performance (retrospective plot of data on paper)	steering demand vs face position plot	Large demands
	steering error vs face position plot	Large errors
	m/c angle vs face position plot	Deviating angle
	m/c speed vs face position plot	All the above relative to speed
	coal reading vs face position plot	Deviations
	predicted coal vs face position plot	Deviations
	roof step vs face position plot	Large steps
checking steering performance (current data on screen)	m/c angle data	Deviating angle
	steering demand data	Large demand
	steering error data	Large error
	coal thickness data	Deviations
	delayed coal " "	Deviations
	roof step data	Large step
	actual boom height	Boom position
	desired boom height	comparison with actual

TABLE 8. Use of Checking Steering Performance Task Information Components Using Retrospective Plots at Collieries

Information Component	**Pit**
	A B C D E F
Steering demand v face position	Y N N N N Y
Steering error v face position	Y N N N N N
m/c angle vs face position	Y N N N Y Y
m/c speed vs face position	Y N N N Y N
coal reading vs face position	N N N N Y Y
predicted coal v face position	N N N N Y N
Roof step vs face position	N N N N Y Y

TABLE 9. Use of Checking Steering Performance Task Information Components Using Current Data on Screen at Collieries

Information Component	**Pit**
	A B C D E F
Machine angle data	Y N N N N N
Steering demand data	Y N Y N N N
Steering error data	Y N N N N N
Coal thickness data	Y N Y N N N
Delayed coal thickness data	N N Y N N N
Roof step data	N N Y N N N
Actual boom position data	N N Y N N N
Desired boom position data	N N Y N N N

The choice of current data or retrospective plots appeared to depend on the electrical engineer's personal preference. Some would prefer to study plots at their leisure in their own office each day. Others preferred periodically to interrogate the current data during a shift, perhaps when they were nearby by chance. How frequently this routine monitoring task was done varied with the frequency of steering problems or difficult face conditions, as one would expect.

At A, both retrospective plots and on-line current data were used, primarily by the elctrical engineer. At B, the MIDAS equipment had been removed some months earlier. At C, only on-line current data were routinely examined by the electrical foreman interviewed. However, both plots and on-line data of steering performance were examined if a problem arose. At D, in spite of the up-to date facility to examine "steering data options" on the top level menu, it was little used to examine current (or past) data. Plots of steering performance were routinely produced, however, for examination primarily by the electrical engineer. At F, plots to diagnose steering performance were routinely produced for examination primarily by a deputy electrical engineer. On-line current data was rarely used, except by a shift charge engineer delegated to monitor steering performance.

Ratings for the task of monitoring steering performance by use of retrospective plots are shown in Table 10. Ratings for the task of monitoring steering performance by use of current steering data are shown in Table 11.

TABLE 10. Ratings of the "Monitoring Steering Performance By Use of Retrospective Plots" sub-task (n = 6)

	Rating				
	A	B	C	D	E
Safety			4	2	
Production				5	1
I-Relations			3	3	
Maintenance			2	4	
LTPlanning			3	3	

TABLE 11. Ratings of the "Monitoring Steering Performance By Use of Current Steering Data" sub-task (n = 4)

	Rating A	B	C	D	E
Safety			4		
Production				4	
I-Relations			3	1	
Maintenance			1	3	
LTPlanning			4		

It will be noted that those who found no need or use for this task did not report it, and therefore gave no ratings. Because of this, the ratings that are given are a priori likely to be reasonably favourable.

Comment: On later versions, the facility to examine steering data is offered as a top level menu option. This appears to stimulate some actual use of the facility, but even so, routine examination of any of this kind of data is patchy. At one colliery, the electrical engineer made a point of examining the steering data at least once a day. At others, including highly productive collieries, such data are examined rarely, or only when an actual problem occurs (see engineering fault diagnosis/monitoring).

4.4.4 Engineering fault diagnosis/monitoring

This heading refers to the use of MSS by (usually electrical) engineering personnel either routinely to monitor the functioning of various shearer components, or to do the same task when a fault is known to exist. Note that checking steering performance and examining delays logs, which could be classed under this heading, have already been described separately above.

Description: The frequency of performance of this kind of task was very variable between collieries. There was no consistent pattern in the use of MSS for this task, other than the production of delays logs

described in section 4.4.1.5 and engineering plots relating to steering described in section 4.4.3. Therefore it is more appropriate to present a brief description of this function at each colliery, rather than present a potentially spurious overall picture. For similar reasons, it is inappropriate to present the task ratings that were obtained, since at best they would be misleading.

The frequency and regularity of this task appeared to be related to the past frequency of problems with MIDAS.

At A, MSS was used for fault diagnosis only when a problem arose. In such cases, the electrical engineer usually operated the system himself and examined real-time data tables, most commonly machine angle, steering demand, steering error and coal thickness. For instance, these parameters were monitored during the period when the shearer drum revolutions were changed from 25 to 38 rpm because drum reaction caused excessive steering demand.

At colliery (B), where a combination of problems led to the eventual removal of MIDAS, MSS was used more frequently to help with fault diagnosis because of the frequency of faults. Tables and plots of current and past data were used when a fault was known or suspected. The mechanical and electrical engineers made the most use of the system in these circumstances. Both real-time and past data were used. Usually, data tables were viewed initially, then plots were produced of transducers vs time when the problem data had been found.

At C the MSS system tended only to be used for examining faults when one had been reported or was suspected for other reasons. Sometimes the routine plots indicated the possibility of a fault, or a report from the face initiated a search for a fault.

At D there was a similar pattern to C. The "engineering options" were used by the electrical engineer if a fitter underground needed to know transducer readings or other information whilst effecting repairs. MIDAS steering errors were usually checked daily. The electrical engineer described the use made of all the options within the top level

menu engineering option. The options below refer to the choices on this menu:

OPTION 1 (tabular display of all current data) used very rarely, but a representative of the shearer manufacturer present at the time said that he found it useful.

OPTION 2 (tabular display of selected current data) used quite a lot to help fault diagnosis or just to check everything is going normally. The data columns are scanned to look for big changes.

OPTION 3 (table of past data) used quite a lot for same reasons as option 2.

OPTION 4 list of MIDAS faults. Every day he uses this to scan all alarms. Many of these arise normally from the way the shearer is being steered, e.g. on the change from manual to auto. He has to eliminate the spurious messages by relating them to normal reasons for the fault. Hence this page should also show say where the shearer was and its status at the fault log time to aid this process.

OPTION 5 (along face plot of selected data) is used sometimes, not a lot. It has its uses for seeing the pattern of things, but data table is used to get digital values.

OPTION 6 graph of selected data against selected time range. Very rarely used. He cannot see the point of it. Normally one looks at things against machine movement or machine position.

There is also an option here for a scattergram. He could not see a use for them.

The seventh and eighth options, past transmission errors and transmission test were not intended for use by people at the colliery.

At colliery (E) there had been a trouble-free history with MIDAS-equipped shearers. Hence MSS had not been used to help diagnose

problems, or to routinely monitor for them, since none had yet occurred. Initially, the electrical engineer examined the log of MIDAS faults occasionally but then stopped because this served no useful purpose while the system functioned satisfactorily.

At F, one person, a shift charge engineer, was delegated to monitor all aspects connected with MIDAS steering and breakdowns. Hence he kept a manual record of delays and their reasons, and problems occurring for engineers. To support this reponsibility, he made occasional use of the MSS system for examining current and past data tables. Unfortunately, he was not available for interview at the time of the study. He also occasionally requested a plot. Usually this was done by the control room operator, but sometimes by himself. Sometimes an oil pressure plot was requested by the mechanical engineer. Other than these uses, MSS was not systematically exploited for fault diagnosis or monitoring at F.

Comment: The electrical engineer at A commented that the system gave no help with fault diagnosis, and had no support for long term health monitoring. For him the most recurrent problem was caused by the roof follower transducer, which frequently needed recalibration after striking roof supports.

The electrical engineer at B commented that the system was very useful for monitoring transducers etc, but the sheer quantity of information could tend to panic people. It was useful in one sense, in that examining past data could be used to break down manufacturers excuses, e.g. to demonstrate that, in fact, there had been a rising temperature when the manufacturers said not.

The mechanical engineer at B said that the use of MSS had enabled three faults to be noticed before they otherwise would have been. Nevertheless, there was little tendency for the system to be used to help diagnose the cause of a fault once it had been noticed. This was because the engineers lacked confidence in the accuracy of surface readings and preferred to use gauges attached to the shearer underground. He expressed the opinion that, in spite of the sheer quantity of information available, he liked the system for its

transducer monitoring capabilities.

The people at colliery C responsible for routine condition monitoring had shown interest in the idea of oil debris monitoring but were still awaiting the fitting of one to the shearer. An electrical engineer commented that the health monitoring transducers were used on the face but the mechanical engineers never used MSS to look at them except for one short period. This was when the roof follower was repeatedly damaged through collision with the roof supports so the pressure on it was checked.

4.4.5 Overall ratings

Interviewees were asked to rate the usefulness of their MSS system as an aid to production, safety, long term planning, industrial relations and maintenance, on a scale from 1 (not at all) to 7 (tremendous help). Table 12 shows the results for the overall ratings in the five areas of interest. Ratings for HQTD and colliery staff are presented separately for comparison.

TABLE 12. Comparison of Overall Ratings of Usefulness of MSS By Colliery and HQTD staff

HQTD (n=4)									COLLIERIES (n=11)							
Rating									Rating							
	1	2	3	4	5	6	7	Mean	Mean	1	2	3	4	5	6	7
PROD				1	1	2		5.3	6.3					2	4	5
I R		1	2			1		1.3	5.4				2	3	6	
MAINT				1	1	2		5.3	3.5		2	4	3	2		
SAFETY	3			1				1.8	3.3		3	4	2	2		
LTP[1]		1			1	1		4.3	1.6	6	3	2				

[1]One HQTD interviewee could not answer, as it would "depend on the manager". Another had had no feedback on this.

PROD = Production
I R = Industrial Relations
MAINT = Maintenance
SAFETY = Safety
LTP = Long term planning

Production: In the main, it was clear from the users' comments, despite instructions to the contrary, that their ratings were influenced by the acknowledged benefits of the MIDAS system as distinct from MSS. Many respondents who had a number of criticisms during interview nevertheless rated MSS highly on usefulness to production. HQTD staff also rated MSS quite highly on its usefulness to production.

Industrial relations: There was an inconsistent view of the effect of MSS on industrial relations between colliery and HQTD staff. Respondents at HQTD tended to think that MSS itself should have little effect. Colliery staff felt it to be quite strongly beneficial to industrial relations. Once again, the ratings were contaminated by the effect of MIDAS on relations - improved production was seen as improving relations because of its effect on bonuses. This is not necessarily related to MSS.

Maintenance: HQTD staff seemed to rate usefulness of MSS to maintenance as an important function. Colliery staff, on the other hand, rated it somewhat lower. Probably the potential is high, but the limited actual use of MSS by mechanical engineers in collieries is reflected in the lower ratings. Also the lack of training or documentation on potential uses of the system for fault diagnosis may adversely affect the ratings given. The fact that two of the HQTD interviewees were commissioning engineers may also help explain the higher ratings given.

Safety: HQTD staff saw no direct connexion between MSS *per se* and safety. Colliery personnel similarly tended to rate MSS as having little impact on safety. A few reasoned that regular plots might enable roof conditions to be better controlled and so increased their ratings a little. Such ratings were based on a conjectured connexion and on knowledge of facts such as reduced timbering required and better visual appearance of the face, rather than actual knowledge of improved safety, which had not been systematically examined.

Long term planning: Opinions at HQTD on the value of MSS for

planning varied somewhat. Colliery staff were more united in giving MSS little or no relevance to planning. This may reflect actual working practice in collieries, and also the lack of MSS support for the gathering of long term trends.

4.4.6 User experience

In general there was no clear connection between the users' experience with other British Coal computer systems and the use they made of the MSS system. Users at all the collieries visited had had some experience with the MINOS coal clearance system. However, this system used a mimic diagram system with a command language and a customised key board, so experience on this system would not be expected to carry over to MSS, except in the most general terms. In one or two cases, the control room operator reported an interest in computers at home as well as work. In such cases the user provides his own motivation to explore and become familiar with the MSS system, almost regardless of how "friendly" (or otherwise) the system is.

Several of the colliery users had had prior experience with MSS's predecessor, System 70,000. This may have helped initial learning and understanding with MSS, but at the time of conducting the interviews, this period can be assumed to have passed, and thus such users showed no clear advantage of proficiency in the use of MSS because of their prior experience with System 70,000.

4.5 Other Issues Arising

During the course of the many interviews conducted, a number of common topics emerged independently from the discussion of the task structure of the users. These issues are developed in detail in section 5 but are reported here since they were raised during the user survey. Where they help to illustrate the point, the users' comments relating to these topics are presented, not verbatim, but in similar language to that used by the interviewees.

Dialogue and System Response Time

Comments on the method and style of interaction with MSS concerned the use of the menu-driven command approach and the system response time between dialogue steps and at the end of a dialogue path. In general, it was felt that the use of menus was an appropriate choice, but some users, particularly with older versions of the software, had difficulty remembering where in the dialogue certain information (perhaps under less frequently requested options) could be found. The delay between dialogue steps often reached 10 seconds. Delays when gathering data at the end of a dialogue path could run into several minutes. These delays were more pronounced when one surface computer was receiving data from two MIDAS faces.

Representative Comments

From Area Engineers: It is tedious to get through the menus. You have to know where your target is to use them effectively. Once a request has initiated processing of data it takes a long time. The delays are even worse if there is more than 1 terminal. (SUP)

From Collieries: Delays on menus are slightly annoying, of course, but the benefits of the system make up for them. At least the system as a whole saves the operator telephoning the face repeatedly to find out what is happening. MSS queries are even made by deputies on a district to see how their face is going. This saves time and effort as well. (D)

The name on menu options is not always the same as the name on the actual plot. This can sometimes cause uncertainty or hesitancy when going through the menus for someone who is not totally familiar with the system. (D)

The system is difficult to use especially for a first-time user. (D)

Ploughing through all the menus is tedious. (B)

Producing Hardcopy: By far the most frequent complaint regarding the MSS system as a whole concerned the producton of plots and printouts. In all installations visited the same make of colour plotter was used. Earlier software did not automatically produce plots at the end of every shift. This added to the operator's time consumed and sense of slowness of the plotter.

The problems commented on fall into two main categories: problems due to the plotter chosen, and problems related to the use of colour plots. Problems in each of these categories are listed below.

Problems due to plotter:

(a) The production of plots is frustratingly slow. This is due in part to the inherent lack of speed of the ink jet plotter used, and partly to the time needed by the computer software to generate the plot. This latter part of the problem is discussed further in section 4.5.3.

(b) The ink jets frequently block up, especially in periods of non-use (e.g. the time between routine plots), requiring the spoilt plots to be redone, again consuming time. This again is caused by the choice of technology for the plotter. Experienced users tend to put the plotter through its self-test routine either before a plot run or before each plot individually, though this is irritating and wastes time.

(c) The paper used does not seem to conform to any standard size, making it awkward to file.

(d) The paper used is not perforated or folded but comes from a roll, making it difficult to handle.

(e) The plotter was unreliable, requiring servicing and perhaps a complete change, at some collieries, even after only a few months use.

Problem due to the use of colour:

(a) The fact that the plots are in colour means that one plot run cannot be photocopied for distribution, necessitating a plot run for each copy required. Alternatively, as at one colliery, one copy of each plot is kept centrally.

It was pointed out by many users that these problems were not created by MSS's predecessor, System 70,000. This system used a standard computer hardcopy terminal (no colour). As a result, output could be printed more quickly, and photocopied if necessary. The fan-fold paper could be handled more easily, and filed more conveniently. However, its output was not so visually attractive as MSS.

The following comments were recorded at interviews, and can be regarded as typical:

From Area Systems Support: Management routine reporting takes the form of plots done at the end of every shift. Plots are automatically plotted from instructions held in a command file in the latest software versions but it previously took up to 3 hours every shift to get them all out. (SUP)

From Collieries: The computer allows a series of plot requests to be issued. These requests are placed on a "queue" held internally by the computer so that the user should not have to wait for one to finish before issuing the next plot request. However, the facility to find out what is waiting in the queue is a menu option only available under system options [This colliery had a recent version of the software, in which the print queue could be displayed.] If the printer develops a fault or is unavailable for some reason (perhaps it has been turned off) the queue remains, perhaps not to be discovered until the next day. (D)

At this colliery the control room operator is required to produce three copies of everything. It takes about 18 minutes, for example, just to plot three of each of the four engineering plots. He has to do these

plots as each shear finishes, otherwise he would not be able to keep up with the quantity of plots on top of his other tasks. There are 5 to 6 strips per shift to plot. He used to plot the delays log but has stopped bothering. The deputy manager has not complained. (F)

Routine plots are put in a filing cabinet, where they are ostensibly available for management. They are done manually at the end of every shear, because of the time taken to catch up with a load of plots if you get behind.

The ink jet set up/test facility had constantly to be used because of frequent blocking. The plotter was replaced 3 or 4 times. (C)

It takes a long time to produce plots and they are not buffered properly - plotting stops the operator from seeing what's happening. It takes perhaps 40 minutes to get all routine plots, whereas the old system (System 70,000) took about ten minutes using an ordinary hard-copy terminal. (A)

The plotter colours often stop working. It is best to do the standard test before each graph. (A)

Automatic Plotting: Later versions of the software had a facility for defining items to be routinely plotted automatically at the end of every shift. MSS without this facility required the operator to specify each plot manually every time the plot was required. This resulted in a much greater load on the operator, especially when multiple copies were required. In one case the operator had a memory aid pinned to the wall to ensure the plots were specified correctly.

Collieries with the auto-plotting facility found it a great improvement over the earlier version, and in general it is much to be preferred. However, the standard plot options can only be altered by personnel (usually from Area) with sufficient password access (see section 4.5.5 for more details). This sometimes resulted in unnecessary plots being produced every shift. It was not thought a sufficient reason to call

out an Area engineer merely to alter the standard plots.

Training and Documentation: There is no standard training applied to the use of MSS specifically. Each colliery seems to make some effort, usually at Area level, to train key personnel in the functioning of MIDAS, and this sometimes includes the control room operator. However, these training periods only incidentally include information on the use of MSS. This can lead to a lack of understanding of the potential of the information system.

Allied to the problem of non-specific training is the lack of provision of any documentation. Control room operators have to pick up their operational knowledge of MSS by trial and error. Their eventual familiarity with MSS depends entirely on their individual motivation and interest. Other personnel have less time and a less superficially obvious requirement to understand MSS so tend not to acquire the necessary skills.

The following comments are typical of those gathered relating to training and documentation:

From Area Engineers: There is no documentation, either for Area troubleshooting people or for colliery users. Documentation would help to give colliery personnel an understanding of MSS and MIDAS which at present is rare. (SUP)

From Collieries: Nobody at all in the colliery has been on a training course. They have picked up all they know by experimenting with the system using trial and error when they have time. 'Days' is a busy shift so the main control room operator is not that familiar yet with the system. (D)

No training for the surface facility was given. For MIDAS itself, the craftsmen, m/c operators and officials went on a course this lasted 2 days, 1 week for maintenance men. Those who were interested could ask and be shown about MSS but no special effort was made to teach it.

Generally the training was based underground, with just a quick look at MSS. (F)

<u>Configuration, Set-up of Defaults and New Software Versions:</u> Several examples were seen of the desirability of allowing configuration changes at a local level. For instance, at one colliery, the auto control limits had been erroneously set outside the bounds of the face. The people interviewed did not seem to be aware that this could be classed as an error. It had the effect that the percent auto and manual figures gave spurious results. Normally the face ends fall outside the auto control limits, so that the normal practice of handing over control to the shearer driver for turn-round can take place. Having the face ends within the control limits spuriously lowers the percent auto figure, and, since the actual operations and speed at the face end are affected by factors outside the control of the shearer operator, the percent auto figure is made more variable. This makes it harder to see underlying trends in the percent auto figure. At another colliery, some of the hardcopy output produced at the end of every shift was not required, but the CRO was not allowed sufficient access by the software to change the standard hardcopy output.

Some collieries did not have the latest version of the MSS software installed, even though it was installed in other collieries in the same Area. This caused some annoyance, since some personnel had heard of improvements made, such as auto-plotting, but were not able to use them.

Comments from Area Support Staff: Configuring of the system presently has to be done by Area because it requires using the computer's program editor under the operating system outside the MSS. MINOS allowed configuration from within the software. It keeps Area people in a job but its a nuisance (SUP).

If there were documentation then it might be possible to configure at pit level (SUP).

From Colliery Staff: Software seems to be upgraded very often.

Somebody seems to come round almost every day (D).

Long-term data compilation All versions of MSS seen during these interviews had very little support for the gathering of data over a time period longer than one shift. Many of the users felt this to be a shortcoming, and felt that it would be useful if MSS could compile a report over a timescale such as a week. In fact, at three of the collieries visited, trends and weekly figures were compiled on paper, in several forms. This undoubtedly takes place in some form at other collieries (with or without MIDAS and MSS) but questions on this issue were not directly asked in early interviews since it is not an actual use of the MSS system.

According to the manager at E, the Area has formed a working party to define standard information flow and requirements for all pits in the Area. Presumably this will eventually define standard summarising sheets which could then be built into MIDAS. Having defined what is required on a summary, at the time of study data had been collected in the standard form for weekly reports for ten weeks.

At E, all routine end-of-shift reports and plots are kept in a folder in the deputy manager's office. The electrical engineer puts them there each morning. At the end of every week he completes an "analysis of cutting" sheet. This contains metres cut, strips cut, percent auto and manual for every shift and day of the week. At the end of the week, totals are calculated for meters cut and strips cut and averages for percent auto and manual. These figures are then made available for management to comment on at meetings. The electrical engineer and management would appreciate it if this were done by MIDAS.

At F a similar task to that at E is performed by a deputy electrical engineer, but in more detail and for a slightly different emphasis of purpose. Two record sheets are kept. The "auto steering" sheet records the average percent auto, average percent steering available, number of strips cut, and comments for each week. Comments record reasons for loss of auto steering availability, such as "2 days lost roof follower

damage". The second sheet is oriented to the numer of strips cut per day, without explicit reference to shifts. For each strip completed, the following are recorded: percent auto, average coal thickness left on roof and standard deviation, the cutting direction, the time of starting a new strip, and any comments. Comments explained reasons for loss of production, e.g. "MMADD count [signal from Machine Movement and Direction Detector] not working".

At D the control room operator records for each shift the percent auto and estimated production and saleable output in comparison to the current target.

The overall purpose of the collection of these data at collieries is clearly to help maintain and improve performance. Any figures that clarify performance figures in furtherance of this goal are obviously desirable. For non-MIDAS faces these are collected and calculated manually but there is no reason why MSS could not provide the required information for MIDAS faces. Some of the required data relate specifically to the performance of the MIDAS shearer. The percent auto and manual figures are monitored because it is usually the case that the higher the percent auto figure, the better the face production and roof conditions.

Figures such as number of strips cut and number of cubic metres cut are in any case compiled and calculated for purposes such as bonus payment and reporting to Area for comparison with similar figures for other collieries and Areas. An extra purpose met by the compilation of these figures by staff such as the electrical engineer is to get a "feel" for the performance trend. For this purpose, exact figures are not required. The data would more easily be assimilated for this purpose if presented in a graphical form.

<u>Quantity of information</u> Some users, particularly managers, whilst being generally in favour of MIDAS and MSS, found the quantity of information too large. Features like graphs were felt to contain broadly the right information, but it was felt that the information

contained in them could be presented in a more compact form. The evolution of paper-based summaries of MSS information in some collieries (see section 4.5.6) also argues for a computerised short-form report.

One manager (E) suggested that the system should produce summary reports in text form on no more than one side of A4 for all interested parties, e.g. face conditions, metres cut, delays etc for managers and transducer and steering function for engineers. Graphs and pie charts look impressive, but they are unnecessarily time-consuming, both to digest and to produce.

Comments from Collieries: The quantity of data should be reduced down to give a management summary. Lots of pretty graphs might be impressive but what do they tell you? (E)

The management used the plots to keep an eye on percent auto, number of shears and roof and floor profiles. For these purposes, a graph is more than is necessary. (B)

The whole system only adds to the paperwork burden. Condensed information is needed. If the information is provided for occasional detailed requests then fine, but digesting the mass of information daily is in itself a job for a computer. The presentation of graphs was itself good, but it could easily become labour-intensive to interpret them all, especially if more than one face were equipped with MIDAS. (B)

The bulk of information is too great and not digested enough. One is interested as a manager only in things that are under one's control to alter, for example, the floor cut, roof cut. (B)

Operator's Updated Display The operator's status display is the most commonly used MSS option. CROs generally were happy with the display, but several requested additional information to be shown. It was felt that the machine position along the face should be shown both by distance (metres or yards along the face) and by roof support number.

Also, CROs would like the display to show the number of strips completed so far in the current shift, and perhaps the total distance cut. These extra items of information were requested to improve the information available for telephone requests.

Comments from Collieries: The machine position must be given in pit units, e.g. chock number. The number of passes so far would also be useful. (A)

The operator chalks the number of strips cut for each face on a board because the operator's updated display does not show this. He is asked about 20 times per hour. He needs to know m/c position, time, length of current delay, whether in auto or manual. (C)

The operator and his foreman gave the opinion that the display should show <u>both</u> the chock number and the odometer position (i.e. position in metres) because people may be used to hearing it expressed one way or the other. (C)

Error messages on this display are irrelevant to the operator. He reads them but does not act on them. (C)

For on-line status the operator usually uses the status page but may choose the steering data display page if flipping from another task, e.g. a plot because this seems to be presented a lot quicker. (D)

4.6 Conclusions

In general there was a high degree of commonality in the main or core tasks performed and the displays used to support them as reported by colliery staff. The most central tasks were monitoring current shearer performance and face management. Other tasks were performed more irregularly or infrequently. These included monitoring steering performance, checking for transducer or data transmission errors, fault diagnosis and engineering monitoring.

The main users of information provided by the SUMMIT system were found to be the control room operators and management staff. The system was under-used for other purposes such as engineering fault diagnosis, checking steering performance and engineering monitoring, compared with the expectations of HQTD development staff.

5. ERGONOMIC ASSESSMENT OF MIDAS SURFACE SOFTWARE

5.1 Introduction

With the contextual information provided by the user surveys, it was possible to carry out a detailed ergonomic assessment of the MSS system. This information, together with additional factors which had been identified during the previous examination of the system (section 2), was used in conjunction with the design guidelines to identify problems and to produce specific ergonomic recommendations for their solution.

During the life of the project, the MSS system was continually being revised and developed and a considerable number of changes were introduced which resolved many of the identified problems. In several cases, such changes were incorporated into newly distributed software at some of the collieries where interviews were carried out. This changing nature of the MSS system was reflected in some of the differing comments received.

5.2 User Interface and Dialogue Techniques

From an ergonomics viewpoint, one of the most immediately striking features of the MSS system is the way in which a range of colours are employed to display text on most of the non-graphical displays. Alphabetic characters are shown in yellow, numbers are displayed in green and punctuation and other special characters are displayed in magenta, cyan or red. Use of colour in this way certainly does not assist the user in any way and will detract from any potential benefits to be gained from the use of colour on subsequent displays. In addition, the differing brightness of the colours used could result in undesired highlighting of particular aspects of a display. However, this selection of colours on text-based screens is not made directly by the software but is a "built-in" feature of the terminal used. The terminal can be configured to display all of the text in any one of a wide range of colours, but it also has an option to use a "smart colour mode". This was selected as the default option to be used by the terminal and produced the observed effect. Although it was possible for this option to be changed by users

to suit their own individual requirements or preferences this fact was not widely known and no instructions on how to reconfigure the terminal were made available.

To select a required option from the menus or to reply to supplementary questions the user was always required to terminate an entry by pressing the return or enter keys. The only exception to this protocol was in the use of two special keys, the escape and backspace keys. Pressing the backspace key would cause the system to abandon the current menu or question and return the user to the menu page that immediately preceded it. Pressing the escape key would also abandon the current operation but would the return the user to the top level menu page. In the earlier software versions there were a few exceptions to this convention. The most disturbing example of these occurred during the periods in which the system was retrieving data from file. This type of operation could take several minutes and could not be interrupted by either key. Consequently the user would have to wait for the data collection to be completed before any inappropriate actions could be abandoned or corrected. Such a situation would tend to cause the user to feel that he was no longer in control and could lead to feeling of frustration and dissatisfaction with the system. Later software versions of the system were modified to correct this potential problem.

5.3 Layout and Structure of the Menu System

At the start of the project, the top level menu (see Figure 3, section 2.2) was more closely related to the individual software components of the system rather than to the functional requirements of the users. The number of options on this menu was in excess of the recommended number and obviously any further additions to the system facilities would tend to exacerbate the problem. In addition to this, the wording of the menu options was felt to be potentially confusing especially for the novice user. For example, the difference between options 2 and 4, "examine current data" and "examine immediate data" would not be readily obvious to any but the most experienced of users. Following feedback from colliery users the menu structure was changed to match more closely their reported requirements. The top level menu (Figure 11) now

displays the four main task categories that were identified in the user survey plus a fifth option "system options" to enable experienced personnel to access and change some of the basic system parameters.

```
                    Surface MIDAS V2.2 operator's menu facility.

Enter the option you require, then press RETURN

 1. OPERATOR'S DISPLAY        4. STEERING DATA OPTIONS
 2. PRODUCTION OPTIONS        5. SYSTEM OPTIONS
 3. ENGINEERING OPTIONS

Enter 1 option :-
```

FIGURE 11. Revised Version of Top Level Menu Page

The second level menu pages contained a list of the options used under each of the general task descriptions. For example, selection of item 2, "production options" from the top level menu would lead to the menu page shown in Figure 12. At the time these changes were implemented, it was impractical to use colour or spacing to further subdivide menu options on each of the pages as this would require changes to be made to all of the software routines that accessed the menu system. In an attempt to achieve a comparable effect, each option description at this level was preceded by a keyword that identifed the basic function of its associated option. For example all of the options that produced pie chart displays were preceded with the keyword "pie".

```
                         Production Options Menu

Enter the option you require, then press RETURN

 1. TABLE - Summary of machine delays per shift
 2. GRAPH - Plot of machine travle through shift
 3. GRAPH - Plot of extraction with respect to seam section
 4. GRAPH - Plot of control quality
 5. GRAPH - Plot of along face altitude for up to 4 passes
 6. PIE   - Machine utilisation per shift
 7. PIE   - Machine tonnage analysis per shift

Enter 1 option :-
```

FIGURE 12. Production Options Menu Page

The other notable problem with the original menu system occurred on the "start time of data" selection pages if the data were to be analysed by machine pass or by shift. The number of data periods available for analysis would often be in excess of the room available on a single screen to display all of the possible options. This situation resulted in the top of the menu scrolling off the top of the display screen. This was obviously undesirable, especially as the most recently recorded shifts or passes were the first to scroll off the screen and be lost from view and it was these options that were most frequently required. Later versions of the software avoided this problem by limiting the number of options offered to the maximum that could be displayed on a single screen. This solution however, has the unfortunate effect that some of the data that would normally have been available for analysis is no longer accessible via the menu options. Although no problems were reported with this approach during the user survey, it may be better to have the final option on such menu screens indicate that more data is available for analysis. Selection of this option could then lead the user to a further page which contained options to select the extra data blocks.

5.4 System Response Time

In general the system response times were within those recommended in the guidelines. The most notable exception occurred whilst the system was retrieving data from file. As mentioned earlier this could take several minutes and, in the original version of the software, the screen would be blank during this process. Because of the nature of the system this length of delay is unavoidable but to leave the screen blank and not inform the user what is currently happening may lead to the user feeling frustration or anxiety. In such situations reducing the variability of the delay and providing a countdown clock to indicate the duration of the delay and the time remaining to completion of the operation would normally be recommended. However, in this case, to extend an already excessive delay would undoubtably detract from the overall usability of the system. To avoid this situation, later versions of the software displayed a message such as: "- data collection in progress -" and then for each block of 200 data points that was retrieved from file a further status line was added to the display. Typical status lines would take the following format:

Data point collected = 200 Data created 21-Oct-1987 08:32.
Data point collected = 400 Data created 21-Oct-1987 08:43.
Data point collected = 600 Data created 21-Oct-1987 08:51.
Data point collected = 800 Data created 21-Oct-1987 09:03.

Although novice users would still not be aware of how long the data collection process was going to take they would at least be assured that the system was still active and collecting the data they had requested.

Delays were also especially pronounced on one of the observed systems that had one computer supporting two MIDAS shearers and two terminals. Delays whilst gathering data could run up to ten minutes. Obviously, delays of this duration strongly discourage any casual use of the system for monitoring or speculative fault finding. They are also incredibly frustrating if one finds that the information pathway through the menus was incorrectly specified and the selection process has to be started again.

5.5 Operator's Updated Display

As reported in the results from the user survey the operator's updated display (see Figure 10, section 4.4.2) is the option most frequently in use during the normal running of the system. This display provides the following information:

Current time of day.
Machine position: chock number or metres.
Direction of machine movement.
Steering status of machine (i.e. auto, degraded auto, manual).
Machine speed.
Report of system errors.
Duration of current delay.

From the results of the user survey, the perceived usefulness of this display would be enhanced if it also provided the following information:

Reason for delay.
Number of passes so far in the shift.
Total yards or metres cut so far in the shift.

All of the data on the current display was reported as being required for the operator's task of monitoring current machine performance with the exception of "system error reports". These reports normally indicate some problem with the data transmission system or errors on which the operator is not required to act. Although it may be useful for the operator to be aware of such errors, as the currently displayed data may possibly be erroneous, there would seem to be little need to require such messages to be acknowledged by needing the space bar of the terminal to be pressed to clear the message. Any such superfluous requirements may in fact cause excessive annoyance and discourage further use of the display.

The control room operator is not permanently seated in front of the MSS display. Hence, the display needs to be readable from a distance of up

to 3 or 4 metres. This requirement is well accommodated by the use of the large (double height, double width) characters currently employed on the display. As there is insufficient room on the display to show all of the required data in this manner, the best practical solution is to use the large characters to display information that is used most frquently or changes most rapidly.

5.6 Management Information

The major source of comment and dissatisfaction reported in connection with the management information tasks during the user survey were related to the slowness of the plotting system and the reliability of the plotter employed. Together, these problems are likely to reduce the effectiveness and total use made of the MSS system: they make it less probable that information is distributed or available to potentially interested parties and they discourage the use of the system for any but the minimum number of routine plots.

The introduction of automatic end of shift plots will help relieve the problems associated with the slow nature of the plotting software but will undoubtedly make reliable plotter operation more important. In fact if the plotter requires constant attention, the usefulness of the automated plotting system is almost completely negated. As these graphs are seen as potentially useful in terms of increasing production, the extra capital investment required to supply a reliable plotter would probably be minimal in comparison to the advantages to be gained, not to mention the amount of operator's time that could be saved.

The provision of management information was not one of the major objectives of MSS. However, ever since the installation of the first MSS system, such uses have evolved. Whether or not the system should attempt to further support this role is a decision that is beyond the scope of this project. However, there is little doubt that provision of such information will help to enhance management opinion of the system and improve general attitude and willingness of colliery staff to use it.

5.7 Steering Performance and Engineering Displays

As described in section 4 many different elements of the available data are used in many different ways at the various collieries to assist engineers to carry out their jobs. Even a single-ended shearer has approximately 50 transducers or other signals that are monitored by MSS. Because of this, it is clearly impractical to examine each combination of data presentation systematically. However, whatever combination of data items is to be examined the display option can be classified as plots of historical data, list of historical data, or tables of real-time data.

The format of the plots used for the graphical display of engineering data conform to most of the general guidelines presented in Appendix A. As these graphs are used to perform such a wide variety of tasks, there is no real advantage to be gained by tailoring the format of such displays to suit specific tasks.

Displays of real-time data are displays which are updated to show the latest value of the selected data items as they are received from the underground system. Such displays are most frequently-used during the commissioning of new MIDAS installations. One notable exception to this is the display typically selected for the monitoring of steering performance. Where this type of display is used to determine the current absolute value of a data item the format employed is generaly acceptable. However, these displays are the only means available for the monitoring of most data items in real-time. As some of the engineering task components require the identification of trends and deviation from a norm, it would be preferable to enable the system to plot graphs of real-time data. Without such a facility, these information components can only be reliably identified by using the plot of historical data, that is data from, at best, the previous machine pass.

Lists of historical data were reported as being used by a few users to help fault diagnosis or just to check everything was going normally. For example, the data columns were scanned to look for big changes.

These lists or data tables were also reported as being used to determine the absolute values for parameters that have been plotted. Data values are typically collected every 2 to 3 seconds for most items. Hence the lists, even for a single machine pass, will be very lengthy and require many display pages to examine an entire list. The paging of these displays was controlled by the operator entering the start time of the data values that were to be displayed on the next page or simply pressing the return key to examine the following page. The utility and usability of such displays could be enhanced by allowing the amount of data for a given time period to be further reduced by, for example, only displaying data that was outside a specified range or displaying mean values for the data.

The large variation in the reported frequency of use of MSS by engineering staff tends to indicate that the use of the system is to a large extent dependent on the individual motivation and foresight of the personnel involved in addition to being dependent on local colliery practise and the frequency of occurrence of problems with the MIDAS system. One of the major potential benefits to be gained from the use of MSS is an improvement in diagnostic and fault finding information available to engineering staff in both a current and predictive sense. However, if the staff are not aware of this potential, or of the manner in which such information can be used, such benefits will not be fully realised. A further indication of the existence of this problem is in the difference between HQTD staff and colliery personnel in the perceived utility of the system for maintenance uses. This problem can be avoided and an overall improvement in system utility realised by the instruction or training of potential users. The optimum form of training or instruction employed would be to a large extent dependent on the previous experience of the users. However, the provision of documentation in the form of a user manual, with examples of how the system could be employed to aid in the diagnosis of faults etc., would go a long way towards raising the user awareness of the system potential.

5.8 User Documentation

At the time of the survey no documentation or other form of instruction was available for the users of the system. This was possibly because the system was still being developed. However, several of the users interviewed commented that even simple documentation, such as descriptions or maps of the menu structure and the information content therein would be a great help.

The user not only had no support for his learning of the system, he was faced with a moving target. The software, especially in its early days, was frequently updated. Menu contents, their labels and their organisation were changed over time. Sometimes a new version would be installed with, for instance, new graph plots available, but no explanation given as to what they were intended for or what they meant. Consequently many of these later additions were not used. One possible solution to such problems would be to provide on-line help or news of new features in each of the software issues released.

5.9 Overall System Considerations

As shown in Figure 2, there are several outer shells to the man-machine system. The MSS system should not therefore be considered in isolation from the many other potential factors. For example, many computer systems are being introduced into collieries and, in particular, into the colliery control room. As a result, users of these systems may be exposed to a variety of differing interfaces and dialogue techniques employed on a range of different computer systems. Such a situation would be potentially confusing and possibly even frustrating to the users, thus reducing the overall effectiveness of all the systems involved.

One of the most frequently made recommendations in guidelines for the design of human computer dialogue is that of consistency. For example, the consistent use of colour, screen location, coding conventions and abbreviations have all be shown to improve performance. By the same token, the performance of the overall colliery control and information

system could also be improved by the use of consistent user interface and dialogue conventions on all of the computer systems likely to be present.

The continued use of a menu based dialogue technique for use with MSS was recommended because the need to accommodate inexperienced and infrequent users was still the predominant requirement. However, as users of the system become more familiar with its operation and gain an increased level of experience, frustration caused by the relatively long and tedius use of a menu system is likely to increase.

There are several potential solutions to this problem. One of the simplest is to allow the dialogue to be conducted either via the menu system or by a command language interface. The users could then select the technique which they found to be most convenient and suited to their level of experience or expertise. However, the major disadvantage of such an approach from an ergonomics perspective is that there is no simple learning path between the two distinct levels of dialogue. That is, the transition between the two techniques is extremely abrupt. A user attempting to change from the menu system, which at this stage he probably knows very well, will again find himself faced with a dialogue technique that is totally unfamiliar and the learning process must start from scratch.

A more elegant solution is to have the command language key words highlighted and used in the menu item descriptions. Selection of menu options could then be made in the usual way or by typing in the keyword. This would lead to the user gradually building up a knowledge of the key words used in the command language. As experience increased the user would be able to recall the keyword sequences for commonly used dialogue paths. When such sequences were entered the intermediate menu pages would not need to be displayed. Eventually the user would become capable of entering the commands as if a command language interface was being used. However, if at any stage he is unsure of the input required, the menu system is still available.

Unfortunately, the additional software development costs that would be

involved in the production of such user interfaces would probable outweigh the benefits to be gained on a single system such as MSS. However, given that the core software routine for such an interface could be developed for use on most of the different systems that are likely to be introduced into collieries within British Coal, the development of such an interface could become a viable proposition. Apart from the benefits that would result from having an interface that was suited to a wider range of users such an approach would also encourage consistency across the range of systems. The total cost of such an interface development would also be reduced by reducing the programming effort involved if producing seperate interface routine for each system.

6. CONCLUSIONS

A number of design features of the MIDAS surface software display system were identified as potentially problematic. These influenced both the ease of use and the acceptability of the surface display element of a successful automated shearer guidance system.

Some of these features were not task specific and, following the distribution of general design guidelines, were readily corrected in subsequent software versions.

In addition to providing direct guidance on ergonomic software display design, these guidelines also served to create an increased awareness amongst system developers of the need to consider the capabilities and requirements of the eventual users.

Some of the design features required contextual information relating to the specific needs of such users and, following the collection of such information in a series of interviews with current users, it was possible to tailor the computer system more directly to cater for these needs.

The actual uses to which the system was put at the collieries differed from those originally envisaged. Some applications, such as its use as a management information system, were not anticipated or therefore designed for in the original system concept. Others, such as its use for preventive or diagnostic maintenance, have apparently not achieved their expected prominence.

A number of aspects of the system contributed to this latter 'shortfall' in expectations. The poor 'user-friendliness' of the early versions of the system, combined with the lack of documentation on its use and capabilities, militated against its ready use on an experimental basis by, for example, colliery engineering staff.

Some changes to the software were produced during the life of the project and have already been distributed to the collieries. It was apparent from reports during field studies that these had been well received and were widely regarded as a considerable improvement over earlier versions.

Finally, the MIDAS surface software system must be viewed in the wider context of colliery computer systems. Disparate design strategies can lead to confusion when colliery staff are expected to attend to a number of such systems. A cohesive overall design strategy would prevent this and would enhance the overall acceptability and ease of implementation of any additional systems.

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APPENDIX A:

ERGONOMIC DESIGN GUIDELINES

1. INTRODUCTION

When producing software the input and output requirements of the associated system must always be considered. For example, to produce a disc filing system the hardware performance of the disc drive and its associated interface requirements must be considered to ensure the fast, reliable and efficient operation of the overall system. By the same token, where the software is to communicate with a user the performance and interface requirements of the user should also be considered.

For a given piece of hardware the performance and data requirements can be specified precisely and must be adhered to for the system to work. The human element of the system, however, is capable of responding to a wide variety of data formats presented via a range of different media. Although the user is capable of adapting to and processing this range of information and hence meeting the system objectives, this does not imply a good system. To ensure the efficient and effective operation of such a man-machine system it is necessary to consider the following factors:

* The environment the user is working in.
* The hardware the user is to interact with.
* The way the user communicates with the system (dialogue).
* The information required by the user.

1.1 The User's Environment

The physical environment within which the user is working must be considered, since factors such as heat, light, noise and workspace layout may well influence the willingness or even the ability of the user to perform the task required, both to interface with the system and to use the software to its full potential. Where adverse environmental factors are known to exist and are unavoidable the user interface should be designed with this in mind. For example, the use of a keyboard bell signal to flag a warning or alarm message might be perfectly acceptable in an office environment but might be of little use in a high noise environment such as a coal preparation plant.

1.2 Hardware

The hardware configuration of a system can also have a large effect on the way in which a user interacts with a system. However the hardware to be used is often predetermined by other system considerations that are to a large extent outside the scope of this document. The required characteristics and suitability of some of the more common devices used for user input/output are discussed in Appendix A.

Throughout the remainder of this document we assume the use of a QWERTY keyboard and an 80 column by 24 line visual display unit unless otherwise stated.

1.3 Dialogue

The type and style of dialogue between a user and a computer system has a large effect on the user's attitude towards it. This in turn affects the efficiency of the total system. The type and style of dialogue best suited to a given application is determined mainly by the user's experience and expectations. If a user is inexperienced and does not know quite what to expect from a computer system a great deal of time and effort may be required to cope with an inappropriate interface. Conversely an experienced user may feel frustrated and held back if expected to use a dialogue designed for a less experienced group of users. Consequently it is important to consider the expected frequency of use and the range of experience of the target user group. If the dialogue causes excessive difficulty or frustration for a given user group, the situation can arise where they feel the effort required to run the system outweighs the usefulness of it.

1.4 Information Requirements

The range of data available on a computer information system is usually far in excess of that required by a user to perform a given task. If an attempt is made to display this range of data, the situation can arise where the information required by a user is spread across many displays and in differing formats. From the user's point of view however, a good system is one that contains all the information required for a single task on a minimum number of screens and in a format that most closely suits the way the data are used. To achieve this objective, it is necessary to consider in detail the task the user is expected to perform. The success of any user-computer interaction is largely a direct function of the designer's knowledge of the user's tasks and requirements.

The following guidelines have been produced without a specific task in mind, they can therefore only indicate the general approach to be adopted based upon broad task characteristics. However, adherence to these guidelines will reduce the risk of at least the gross problems which may otherwise arise.

2. DIALOGUE DESIGN

2.1 Introduction

This section describes the general features of dialogue that make for a good, friendly and easy-to-use environment for a user interacting with a computer information and monitoring system.

The term 'dialogue' in this context denotes a set of input and output procedures by which a user communicates with a computer system, and vice-versa. A user needs to feel that the computer is there as a tool to be used and this feeling is determined in part by the tone and sequencing of the discourse between the user and the computer.

Users of an interactive system quickly build up a feeling of style and quality of the system. The main factors that have been shown to make the difference between good and bad systems in terms of user-perceived quality are:

Self-descriptiveness. This allows the user to learn the system through trial and error with machine feedback. The computer should always tell the user what is going on to help build an understanding of normal and abnormal running. For instance, if the user has just asked to edit a text file that does not exist, the system should say so, and say what it is doing instead (e.g. creating a new file for editing).

User control and flexibility. It should be easy to interrupt, abandon or change tasks. For example, if the user has asked for an operation that needs extensive file-searching which may take several minutes but then decides the operation was specified incorrectly, then it should be easy and apparent how to abandon the task. The system should always give the feeling that the user is controlling the interaction and what is happening. Anxiety decreases learning, particularly for novice users.

Ease of learning. Make sure that subtle details of terminology and syntax are adequately explained. This factor is much more important for casual users than regular users.

Task-adequate usability. Minimise the details that the user must know and deal with for each task, and avoid giving details not needed for the tasks. For instance, a user does not need to know (and would be confused by) the intricacies of disc filing in order to save a word-processing file.

Correspondence with user expectations. The system should behave in ways that the user has learnt to expect. For example, if in one circumstance the user has found that the backspace key takes the system back to the previous menu page then it should have a similar effect in other circumstances.

Fault tolerance. The user should easily be able to rectify mistaken commands or responses.

2.2 Consistency

It is important that different points within the user dialogue are consistent with each other in style and logic. One of the strategies adopted by users initially getting to grips with a system is to extrapolate from early examples to new situations. So if the inferences the user makes about the system are true sometimes but not always, then learning is impeded and the amount of errors and frustration increased. This general principle should always be applied but leads to a number of explicit recommendations:

Use consistent areas of the screen for showing prompts, user's responses, normal and abnormal system responses.

The screen can be divided into windows, either notionally or visually, with different types of interaction in different areas. The user soon learns where to look for needed information as familiarity with the system increases.

Use coding conventions consistently.

It confuses and disrupts a user's previous learning if coding conventions are used in different ways throughout a system. For instance, if red text is used for a warning message in one context then do not use it elsewhere for messages that are not warnings.

2.3 Dependency on Operator Experience

Duration, frequency of use of the system and training influence the appropriateness of different dialogue methods. The dialogue style should be matched to the training, familiarity, frequency-of-use and tasks of the users.

At one extreme, if users are not at all familiar with a keyboard and use the system infrequently, then the interaction needs to be tightly constrained and the acceptable 'language' or response always made explicit. For casual or infrequent users, ease of learning is more important than for experienced users. With a highly experienced user working with a computer several hours a day, a full language for interaction can be built up and full instructions at every step in the dialogue are not necessary. If the target user group is likely to cover a range of experience levels it may be desirable to allow a choice of dialogue methods (e.g. menus, form-filling, command languages). If this is impracticable, the dialogue should be suited to the least experienced of the users. A training programme may be appropriate, to ensure that the users reach a minimum level of competence with a new system.

2.4 Error Correction

When entering data or giving instructions an operator inevitably makes some mistakes. Good design reduces but does not eliminate their likelihood.

Users should always be given the opportunity to correct an error or modify an input.

The system should always permit the interruption of its current operations to allow the user to correct mistaken input. In ordinary conversation, it is extremely annoying to have to wait several minutes to get a word in edgeways to correct the wrong impression that was made by something one said. Likewise with a computer. It can be very frustrating to have to wait until a command has been fully processed before being given the opportunity to say that actually you did not want to do that. The frustration stems from the computer taking control of what is happening from the user.

2.5 System Response Time

Another potential source of frustration is the computer's response time to commands. In general a delay in the computer's response is acceptable only if it is in proportion to the perceived difficulty of the requested task. An immediate response is not always required. The figures shown in Table A1 are an approximate guide to acceptable system delays for typical tasks.

TABLE A1. Acceptable System Delays for Typical Tasks

Classification	Delay (Secs)	Comments
Within a dialogue:		
Echo	< 0.1	e.g. click of keyboard, visual feedback on VDU.
Conversational requests	< 2	e.g. most editing tasks, routine interaction on course to a task.
Searches: String search requests	< 4	Two-second delays are preferable unless the user is likely to perceive the request as a complex enquiry.
Browsing, page-by-page search	< 0.5	Longer delays, at least for the first few lines of the next page, are intrusive on the continuity of thought.
Task completion:		
Program execution	< 5	If continuing user interaction is required, the delay should be less than 5s.

Longer delays than these reduce performance by increasing frustration and the possibility of distraction or error. If response delays of more than 15s are necessary then the task should be designed to free the user from activity (i.e. no interaction for the delay period, no necessity to remember where in the task the user had got to) so that the user can do other work and return to the display when it is convenient.

When a user asks for complex calculations (and there is an awareness of this), then there is more tolerance for a delay between request and response. But consideration of the delay times alone is often not sufficient. For example, a predictable but slightly longer delay is usually preferable to a generally shorter but highly variable delay.

A display which is blank or static following a request for action is unnerving. When the user is required to wait the computer should give notification of this; for instance, if a request for data necessitates extensive file-searching, thereby slowing down the response time markedly, the user should be told what is happening. Preferably the display should give some dynamic indication that processing is continuing such as a count-down clock arranged to reach zero on completion, or a display of time to completion. This again allows the user to do another task. A static message may mislead the user into

thinking the task is continuing when in fact the system has crashed; just one occurrence of the system leaving a 'normal running' message on the screen when it has crashed shakes the user's future confidence in such messages.

3. COLOUR

3.1 Introduction

There are three ways of using colour in the construction of displays:

(i) As a supplementary coding method to others, such as spatial location, labelling, shape and size, etc.

(ii) As the sole or unsupported method of coding display information, e.g. colour changes to show change of status.

(iii) To increase the aesthetic appeal of the display, without necessarily enhancing the function of the display.

3.2 Supplementary or Non-Essential Coding

Supplementary coding is a very effective way of increasing the efficiency of display usage, provided the use of colour has been planned with respect to other methods of obtaining information used in the display.

When colour is used with another 'code' such as text labels, symbols, etc, then colour is considered to be supplementary, as it is not the only means by which the information is being conveyed. For example, if a status label changes from 'stopped' to 'running' and also from red to green, then colour is being used as a supplementary code to the text label.

As a supplementary code, colour has been found to be very effective in search tasks, i.e. those in which the user knows the target and has merely to locate it. For instance, when searching through a large menu, if items of the same type (pressures, temperatures, flow-rates etc) were grouped together and colour-coded this would reduce the number of items which had to be scanned every time the menu was used. The use of colour coding in this way has been found to reduce the time required to search for information in a display by up to 70%. Of course, this presupposes that the grouping of the menu items corresponds to groups of information required by the user.

Used as an supplementary code colour can be used to improve performance of a number of search and locate tasks by:

* Relating or tying fields into groups.
* Differentiating groups from each other.
* Relating data that are spatially separated.
* Calling attention to important data fields.

When colour is used as supplementary or non-essential coding up to five colours may be used.

3.3 Colour Unsupported by Other Coding

Unsupported colour coding is a very effective method of obtaining information related to some tasks, provided the colour codes are known, relevant and limited in number.

When colour is the only form of coding this means that the display does not use any method other than colour to convey information contained in the display. For instance, if the status of an item of equipment on a display is shown by its colour (e.g. green is running, red is stopped) and the display shows this information in no other way, then colour is the only form of coding for its status on that display.

If the code is not related to the user's expectations or experience there will be more difficulty in remembering it, especially at times when a quick response is needed. Because the colours in the display are the only means of obtaining information their meaning must be known from the start. Conversely, with supplementary coding one can allow the meaning to be learnt through experience.

The main uses of colour as the only method of obtaining information from a display are:

* To identify kinds of data.
* To identify sources of data.
* To identify status of data.
* To show order of operations.

Do not use more than three colours if consistent and accurate recognition of the code is important.

Beyond this number one hundred percent accuracy becomes increasingly difficult. It is therefore important to know the consequences of inaccurate monitoring (e.g. in terms of effects on quality of product or on safety).

3.4 Aesthetic Appeal

It is accepted that the use of colour may increase the general interest and the commercial appeal of a display. On very simple displays its use for aesthetic reasons is unlikely to have any adverse effects on task performance (although it will not improve performance either). However, as display complexity increases so does the potential for the inappropriate use of colour to affect performance adversely. This is mainly because colour is such a powerful coding medium that it tends to be processed at the expense of other coding methods. Therefore, it is generally recommended that:

Colour should not be used to increase the aesthetic appeal of a display without considering the possible adverse effects on user performance.

Some of the possible adverse effects on task performance are:

* Colours can have specific meanings for the user which were not intended by the designer.

* Display items shown in the same colour may be visually grouped in a way that is unrelated to the task to be performed or is in conflict with another task-related group of items.

* The inappropriate use of colour in one display may interfere with its attention-gaining powers in further displays.

3.5 Selection of Colours

If poor colour combinations are chosen, they may be mistaken for or confused with other colours. The extent to which this occurs depends on the application. For instance, there is a greater chance of colours being mistaken for each other in graphs where the areas of colour are small and may run close together or overlap.

Eight percent of the male population have defective colour vision. Rather less (approximately one percent) of the female population also have this problem. For example, people with a red and green colour deficiency (the most common) have problems distinguishing yellow-reds from yellow-greens and brownish reds from brownish greens, although some combinations are distinguishable by luminance. Therefore such colour combinations should not be used as an unsupported method of coding where operators have not been screened for defective colour vision. However, the use of pure reds and greens is acceptable as such combinations are distinguishable by luminance as well as colour.

Use colours which are as far apart in the visual spectrum as possible.

Typical good combinations of colours are:

* red - green - blue
* black - yellow
* green - white
* red - white
* blue - white
* yellow - blue

Typical undesirable combinations of colours are:

* orange with red or yellow
* yellow with green
* violet with blue

When selecting colours, it should be remembered that the appearance of a specific colour may differ according to features such as the brand of colour monitor, dust on the screen, the spectral content of the overhead lighting, the preferred level of the setting of brightness controls by different operators, etc. Therefore, although the colour combinations referred to above have been found to be advantageous experimentally their effectiveness should not be assumed without considering their appearance in combination with the expected equipment and environment.

Remember that dark backgrounds make colours appear lighter than they really are and vice versa for light backgrounds. Colours should therefore be chosen according to screen background colour so that they

are discriminable but are not uncomfortably bright with the possibility of masking other colours.

. Different colours are compatible with different sizes of display area. For example, blue is useful for large areas but in small areas, e.g. symbols, it may be difficult to discern. This is due to its low luminance compared with other pure colours, which work much better for small areas.

When different colours are used in close proximity or cross each other, e.g. coloured lines as used in process control displays, care should be taken that bright colours do not mask others.

Some colour codes may already be in use by particular population groups. If this is the case, and these codes do not conflict with other system conventions, use them. This avoids the users having to learn new and possibly conflicting conventions.

4. MENUS

Menus are recommended for occasional and novice users as they reduce the amount of information the user needs to remember. The major disadvantage of menus is that for more experienced users they may be ungainly and long-winded. The possible areas of application for menus range from the use of a single page menu for the selection of two or three possible program options to the use of multiple page menu systems for the selection of data in a large data base.

4.1 Structure of Menu Systems

Given a fixed number of options or possible goals, a menu system can be arranged with many items on each page and a minimum number of pages (broad), with few items on each page and many pages (deep), or anywhere between these two extremes. On each menu page the user's task is to scan the options available and to select the most appropriate one. The format and layout of menu systems should be arranged so as to assist the user in these basic tasks.

In general, broad options are considered to be superior as they reduce the number of pages and options to be selected and hence the potential for errors to be made. However, there are limits to the number of options a user can easily deal with on each menu page.

Menus should be structured in a hierarchical or "tree" manner.

A series of menu screens should be structured in a hierarchical or "tree" manner with the primary or basic choices on a main screen and lower-level choices on lower-level screens. This type of menu structure is recommended as it is the simplest logical structure for the user to remember and to work with. It helps the users to remember where they are in a menu system and to find their way through it.

4.2 Number of Options Per Menu Page

Menu options can be considered as being one of two possible types. They can be descriptors of a general nature such that they describe a subset

of possible options, features or data sets. Or they can be descriptors of specific options, features or data. When the options on the menu are of a general nature, naive users need to consider all of the options available in order to determine which one is the best description or "match" to the desired operation. When the options are of a specific nature, users do not need to consider all of the options; they simply have to perform a search and locate task, terminating on location of the appropriate option.

For general options use no more than 6 to 8 options per page.

When the options are of the general type a maximum of six to eight per page is recommended. However, if the options can be divided into distinct subsets, and the order and layout of the page is structured to show this, it is acceptable to have up to 16 options per page.

For specific options use no more than 50 to 60 options per page.

Where the options are of the specific type the limiting value for the number of options per page is normally determined by the space available on a single screen but should not exceed 50 to 60 items. Care should be taken to ensure that the list of options do not become too crowded or cluttered. Abbreviations should not be used purely to force the options onto a single screen.

4.3 Wording of Menu Items

Menu item captions should provide a clear, concise, fully spelled out description of the alternatives and choices available.

Abbreviations should only be used where they are consistently used and generally recognised by all of the users. Words to describe the options should be consistent with those used both throughout the system and in the user's working environment.

4.4 Routing Information

Each menu frame should uniquely identify itself and indicate the action required from the user.

This information should be given in a consistent spatial location and should be visually distinct from the rest of the menu text. The use of a unique colour and/or reverse video is effective in this context.

4.5 Layout of Options

Menu items should be left-justified and aligned into columns.

For ease of scanning, menu items should be left-justified and aligned into columns. Position the groups of aligned items around the centre of the screen and do not use extra spacing to right justify the text. Do not spread out the options merely to fill space on the screen.

4.6 Ordering of Items on a Menu Page

The best order is dependent upon the number of items to be included and

their usage characteristics.

For eight or less items:

Where the pattern of usage is known, order them by frequency of use. If no obvious frequency or pattern is known use alphabetic order.

For nine or more items:

Use an alphabetic order whether or not the usage pattern is known.

When alphabetic ordering is to be employed, sort the options based on the underlying keyword within the option description. In such situations, it is preferable to have the descriptions start with the keyword. However, if this is impracticable, highlight the keyword within the descriptor.

Grouping:

When an appropriate logical grouping of data items into subsets is possible group the items and use alphabetical ordering within each group.

Each group should be spatially separated, preferably in a separate column. Avoid splitting groups, for example, do not start a group part way down one column and continue at the top of the next. The use of colour coding to highlight the different groups is recommended. Where sufficient space is available, it can be useful to label the different groups with headings. This assists the user in identifying the function of the groups.

4.7 Selection of Options

There are many ways in which the user can be allowed to identify and select the options required. The optimum technique to use is determined by:

* The type of hardware in use.
* The layout and complexity of the menu system.
* The user's experience and expectations.
* The number of options to be selected from each menu.

All of these factors should be considered when selecting the technique to be used. If the menu complexity is to vary throughout the system select the technique that best meets the requirements of the most complex menu.

Do not use different selection techniques for different menus.

The instructions to the user should explicitly state the input format or action required to select an option. Where multiple selections may be made from a single menu, it is helpful to identify those items that have already been selected. For example, this may be achieved by using a change in colour or the use of a flag next to the item such as a pointer or asterisk.

Several different approaches to identifying the menu elements to be

selected are available:

Ordinal Identification. Items are simply numbered according to their column position and the user is requested to enter the number of the option required. Ordinal identification and selection may be used on simple menus where the user is not expected to remember or to use the identification numbers on other screens. Always place a full stop after an item number, separate by at least one space from the captions and use numbers starting with one, not zero.

Mnemonic Identification. Each menu item is associated with a mnemonic code or abbreviation. The user is required to enter the relevant mnemonic to select the item. The mnemonic may be placed alongside the option caption but it is better to highlight the mnemonic within the caption if possible. Colour or increased brightness is the best way to achieve this. Mnemonic identification and selection techniques are useful for more complex menus, as the user is likely to learn the codes through experience. This can lead to a rapid increase in performance especially when the user is permitted to enter options before or without the menu being displayed. However, in order to achieve this, the mnemonics or abbreviations must be chosen very carefully.

Cursor Selection. The menu item captions are displayed without any further form of coding or indentification, the cursor or some other displayed pointer is then positioned next to the required option and a function key used to indicate its selection. Where manipulation of the cursor or pointer is performed using discrete keys such as the cursor control keys this technique should only be used for menus with a small number of items. If however a device such as a mouse or tracker ball is available, it is reasonable to employ the technique with larger menus.

5. GRAPHS AND CHARTS

5.1 Introduction

This section describes design guidelines for the graphical presentation of data. For the specialised application of monitoring several process control parameters simultaneously, this section should not be used. Some guidance is given in Appendix B, though it may be advisable to contact the Ergonomics Branch for further advice on specialist displays.

The first few subheadings describe the use and design features of several kinds of graph and chart. The remaining subheadings describe design features common to these graph types, such as labelling, divisions on coördinate axes, use of colour.

Use graphs and charts for showing qualitative aspects of data. Do not use them if the prime purpose is to show exact numerical or quantitative data.

Displaying qualitative aspects of the data allows the user to grasp the meaning or significance of the data in some particular context. The presentation of exact data must at most be of secondary importance. Usually the user is expected to make comparisons and appreciate patterns in the data but not to perform exact calculations with the displayed

data. For example, graphs and charts are good for:

* Showing trends.
* Making comparisons.
* Spotting deviations from the normal.
* Showing the division of a whole into parts.

No one graphic format is universally superior. But though some formats can be interchanged, there are limits. Each format has its domain of application, which may overlap the domain of other formats.

5.2 Simple One-Line Graphs

Use a simple plot of one line on an L-shaped graph if you want to show the relationship between two variables.

A line graph is suitable if, for instance, you want to illustrate that oil pressure decreases with temperature.

Where the user has to extrapolate, interpolate, compare or classify trends in time and does not have to read off exact amounts, line graphs are superior to bar charts or tables. An exception is when there are few time periods with large changes from one period to the next, in which case a bar chart is equally effective.

5.3 Multiple-Line Graphs and Multiple Graphs on a Page

It is possible to show several lines on one graph or to have multiple graphs on one page or screen. For reading approximate values of points, either multiple-line graphs or several graphs on a page are equally good. But for comparison tasks the multiple-line graph is superior. In general, colour-coding improves the performance when added to other coding, especially for multiple-line graphs.

On multiple-line graphs, the line codes (e.g. symbols) should be chosen to have minimal confusion. There should not be too many lines on one graph - the limit could be as low as three if they cross frequently. On multiple-line graphs, axes should preferably be repeated at the top and the right-hand edges of the graph for easier reading of extreme values, unless this results in an unduly cluttered or cramped display.

5.4 Bar Charts

Use a bar chart for comparing relative quantities of items or categories of a variable, or for taking approximate numerical readings.

If the user's task is to compare the relative quantities of a number of different categories or items and see the approximate amount of each, then a bar chart is generally the best choice. A pie chart may seem suitable, but comparisons of the linear height of bars are made more accurately than comparisons between segments of a pie, where the judgement is of angle.

Bar graphs are also the best format for taking an approximate numerical reading, e.g. to see whether a variable has reached a remembered upper limit. It is much easier to make mistakes using a line graph. If the

user is likely to be interested in the exact numerical value of a bar as well as compare values, then the values can be shown on the chart at the end of each bar.

If bars are broken to fit them on the screen the user is no longer able to judge the relative lengths of the broken and unbroken bars though, it is still possible to judge the order of the lengths.

Make bars wider than the space between them and do not allow grid lines to pass through bars.

Extra spacing and grid lines through bars disrupt comparison of bar height.

There is no particular preference for a horizontal or vertical bar presentation, except that labels can usually be more easily accommodated on a horizontal chart.

If you want to reflect large changes from period to period but have very many periods, then a bar chart with no separations between bars can be used, to avoid the appearance of a picket fence.

5.5 Pie Charts

Use a pie chart if it is particularly important to convey the concept of a whole divided into parts but fine relative judgements of quantity in each slice are not so important.

Usually, bar charts are better if the user is to make relative comparisons of quantity of items, or categories of a variable.

Limit pie charts to five or fewer segments.

Comparisons between many thin slices are inaccurate and difficult to do.

5.6 Labelling

The elements of charts and graphs should be labelled directly rather than indirectly by key.

Horizontal bars give room for labels and figures on or near the elements. This is the chief reason for preferring them to vertical bars. Multiple lines on one graph should be labelled on the graph if there is room, even if supplementary coding such as colour is used. If space is restricted, abbreviations may be used to reduce the space needed to display captions. Guidelines for constructing these are given in a later section.

Write axis labels horizontally.

It is better to label the ordinate horizontally at the top left-hand edge of the axis than to label it sideways. Take care not to confuse the label with anything which might be in the heading area.

5.7 Scales

Make the axis numbers large enough to read easily.

Do not display numbers on a scale smaller than the character size on an 80 column text display. If the guidelines for numbering of scales are followed, there is likely to be room to make them somewhat larger than this.

Use scales that make interpolation easy.

Tick marks should be placed at each number on the scales. Grid lines should be added only if they are essential to aid interpolation. Remember that a graph should not have been chosen if the user needs to know an exact reading, so a fine grid of lines as on graph paper is not necessary or desirable. If the task is to spot when a line has left acceptable bounds, lines should be used to indicate normal limits or alarm levels.

Examples of preferred scales are:

1, 2, 3, 4, 5, ...
5, 10, 15, 20, 25, ...
10, 20, 30, 40, 50, ...

Examples of acceptable scales are:

2, 4, 6, 8, 10, ...
20, 40, 60, 80, 100, ...

Avoid using scales like:

3, 6, 9, 12, 15, ...
4, 8, 12, 16, ...
0, 2.5, 5, 7.5, ...

Graphs should never have more than one scale on one axis.

Use linear scales unless <u>all</u> the users are familiar with another type.

Unless users are familiar with alternative types of scales, such as logs, they have difficulty in interpreting them.

Generally the scales should be arranged to exceed slightly the maximum and minimum ranges of the data, so that patterns in the data are not disguised by compression of the scale. Autoscaling may be desirable as an option for graph plots on VDUs, but it may make it more difficult to compare graphs. If the ranges of the data are known in advance, it may be better to have a fixed scale for each different type of data.

In some cases, choosing the scaling (or allowing autoscaling) to make the plotted line fill the graph changes the perceived variations in the data by altering the slope of the line between points. Try to arrange the graph so that normal variations in the data (not sharp or abnormal changes) are represented by line slopes of no more than about 30 degrees. Above this angle, users are more likely to perceive the line as sharply changing, when the data do not warrant this interpretation.

If there is a large amount of point-to-point variation which has no particular significance for the user, then consider smoothing the data or plotting an interpolated line to show hidden trends or patterns.

5.8 Coding in Graphs and Bar Charts

Colour-coding is more effective than other coding such as shape when used on its own. But use of colour as a supplement to other forms of coding is best.

The Colour section gives more details of this form of coding. Shading or hatching can be used on bars but take care that the patterns are not too garish. If there is a logical order to the shades then use the darkest pattern for the highest extreme and the lightest for the lowest extreme of the order.

Make curves visually distinct from each other and from the grid.

Use symbols, colour or line pattern to indicate different lines on a multiple-line graph. In some cases it may be better to reserve dashed lines and patterning generally for the grid or for line projections or extensions.

6. TABLES

6.1 Introduction

The guidelines in this section are primarily for application to static collections of numerical data organized and classified into columns and rows. They do not advise on specialised forms of table, such as dynamically changing lists, spreadsheets, etc, though most of the guidelines given here are relevant.

If the purpose of using a table is to allow visual quantitative comparison then a good table should show the patterns and exceptions in it. If a table is needed to allow a quick look-up of a figure then the organization of the rows and columns should facilitate this. You should ensure that row and column information is complete and that all relevant levels of categories are displayed in a terminology familiar to the user. Wherever possible, avoid making the user interpolate or draw inferences to find the needed information.

In general, as the number of conditions presented in a table increases, the table gets harder to understand and use. Sometimes it is better to simplify by creating two or more smaller tables.

6.2 When to Use

Use tables if the user wants to make quantitative comparisons or look up exact numerical information.

Otherwise, graphs and charts are more appropriate.

6.3 Rounding

Show numbers only to the accuracy that the user needs.

One of the points of giving data in tables is to allow quantitative comparison. Most of us can do mental arithmetic efficiently with only one or two digits so it makes a comparison task more difficult to report numbers to more than two significant figures. Often, numbers are reported well in excess of the true accuracy of the data. If a table of exact data is needed as a record then this should be given separately. The same table should not be expected to give an immediate understanding of the data and also form an exact record.

In the example shown in Table A2, two tables are combined into one to illustrate the importance or rounding. The prime figures for visual comparison are presented in columns. In the left-hand half of the example, notice how the rounding of the number of deployments and the change on the previous year makes it easy for the eye to make comparisons looking down the columns. The figures affected by an industrial dispute stand out and the deployments in July and August drop as men take holidays. The 'change on last year' column quickly shows the overall improvement in attendance after the industrial dispute compared with the previous year. As a comparison, look at the right-hand half of the example, where the same data are not rounded and the presentation is 'for the record'. It is much harder to see the trends and exceptions in the data.

6.4 Row and Column Summaries

Where appropriate, give summary figures to rows and columns.

Often, marginal figures giving totals or averages of the rows and columns help the user see patterns in the table more quickly. In the example above, the 'change on last year' column fulfils this function in a way. If the table columns had shown a breakdown of reasons for non-deployments (e.g. holidays, disputes, official business, sickness, accidents) then a useful row summary would have been 'Total non-deployments', with perhaps 'Yearly average' summarising the columns.

6.5 Arrangement in Columns

If the user's task is to compare figures, then put them in columns, not rows.

Figures are easier to read following down a column than across a row, especially for a large number of items, so use columns for the most important comparisons. Minor variations and sub-patterns are more noticeable in columns, especially if the figures are well rounded.

Look at the left-hand half of the example above. The most important comparison one would expect the reader to make is the seasonal variations in the figures. That is why months are arranged down the side of the table so as to make the seasonal variations fall into columns.

6.6 Ordering of Rows and Columns

Rows and columns should be ordered by the numerical size of each

TABLE A2. Illustration of the Use of Rounding

*Rounding to facilitate visual comparison — *Exact figures given 'for the record'

DEPLOYMENTS PER MAN						
Month	Possible	Actual	Change on Last Year	Possible	Actual	Change on Last Year
1985						
January+	20	6	-6	20	6.17	-5.67
February+	20	8	-9	20	7.62	-8.57
March	25	17	3	25	17.46	2.94
April	20	14	10	20	14.38	9.66
May	20	15	12	20	15.03	10.41
June	25	17	10	25	17.46	12.48
July	20	14	10	20	13.70	9.71
August	20	13	9	20	13.06	9.14
September	25	19	13	25	18.83	13.16
October	20	16	11	20	16.42	11.39
November	20	17	11	20	16.69	11.13
December	25	18	11	25	17.51	11.02

* Source: Number of deployments per man, national trends monthly for year to January 1986. NCB Statistics Dept, KF7(STM 1/11).

\+ Attendance affected by industrial dispute.

figure, not by the structure of the row and column labels, if it is appropriate to the purpose of presenting the data to do so.

In Table A3, we suppose that one of the purposes of showing the data is to draw attention to the actual deployments of men that are highest, rather than just to present the data in monthly order for the record.

With the highest deployments at the top of the table one immediately sees which are the months with highest attendance. The figures affected by the industrial dispute (when attendance was less) fall to the bottom of the table. If the purpose of the table were to show up the effects of the dispute then the table would be better the other way round with the lowest actual deployments at the top.

Ordering rows or columns by some measure of the size of the data (e.g. average) allows one to see the structure to the data, rather than the structure to the column and row labels (which is usually well known).

TABLE A3. Ordering Rows to Facilitate Visual Comparison

DEPLOYMENTS PER MAN*		
Month	Possible	Actual
September	25	19
December	25	18
March	25	17
June	25	17
November	20	17
October	20	16
May	20	15
April	20	14
July	20	14
August	20	13
February+	20	8
January+	20	6

* Source: Number of deployments per man, national trends monthly for year to January 1986. NCB Statistics Dept, KF7(STM 1/11).

\+ Attendance affected by industrial dispute.

6.7 Spacing and Layout

Use spacing and layout to facilitate the eyes' travel down columns and along rows.

Do not spread tables out merely to fill space. Conversely, do not use an excessively small typeface just to accommodate a very broad table. Instead, divide the table into two or more smaller ones.

Figures that are meant to be compared should be placed close together, so single spacing is effective in letting the eye read down columns. There is also a need for the occasional gap between rows to guide the eye across the table. Where possible use gaps to help identify subgroups within the data. For example, gaps have been used to help show the quarters on the first two tables. Otherwise gaps should be left every five rows or so.

Ruled vertical and horizontal lines are useful around the borders of tables and to separate captions and labels from figures. Lines between columns and rows of data do not bring particular benefits so long as the spacing is sensible. On an 80 column display, provide at least two character's space between columns that are not separated by vertical rules. Colour can also be used to differentiate column and row labels from cell entries.

Columns of figures should be aligned so that the same units lie on a vertical line (e.g. thousands, or the decimal point). If all the figures contain a number of trailing zeroes then chop them off for the sake of clarity and explain the size of the numbers in the title (e.g.

"'000s".)

6.8 Labelling

Label tables, saying what they contain.

You should give a short explanation of the contents of a table at its head. If longer explanation is necessary you can give this in a footnote. Usually column and row labels should be given in full, but abbreviations can be used if you are sure that they are well known to the user. Where applicable, units should be given. Again, footnotes can be used if necessary. Column labels should be placed at the heads of the columns; row labels should be shown at the left of the rows. Make sure it is clear to which column or row they refer.

6.9 Look-Up Tables

Try to arrange the table so that the user can look up a desired figure using one dimension rather than two.

A user is performing a look-up task with a table if the objective is to find the figure in one of the cells by using the categorization structure of the table. The most common way to structure a look-up table is to use two or more dimensions (sides to the table) as a way of cross-classifying the data. For example, in the tables shown above, the rows giving the month of the year form one dimension and the columns giving deployment figures the second dimension. If it is practicable within the space available on the screen or page it is preferable to put both the dimensions along the vertical axis as shown below. This makes the user's task quicker and easier and reduces the chances of error.

TABLE A4. An Example of a One-Dimensional Table*

MANSHIFT TYPE	AREA	% OF TOTAL MANSHIFTS WORKED
Development	SCT	18
	NEA	30
	NYK	21
	SYK	20
	NDY	17
	NTS	15
Production	SCT	22
	NEA	16
	NYK	19
	SYK	22
	NDY	30
	NTS	28

* The table is laid out on the assumption that the user wants to look up manshift figures broken down by area. The abbreviations used for the Area are industry standard and would be well known to users of this type of data.

Source: Distribution of labour, 4 weeks ended 22nd February 1986. British Coal Statistics Department KF 11 (STM 1/13)

7. TEXT ON VDUs

7.1 Introduction

This section deals with writing and laying out ordinary text on VDU screens. Appendix C deals with other recommendations on writing and laying out text which are appropriate for consideration on VDU displays but are based exclusively on studies of paper-based text.

7.2 Structure and Paging

Remember that screens are not made of paper. Having the whole text on paper is itself a 'navigation aid' so readers at all times know where they are in the document or can refer to the Contents or Index. It is easy to lose this when manipulating text on screen. Looking backward or forward in a sequence of pages on screen can be made unintentionally difficult: even short system delays can be sufficient for readers to forget information that links what has just been read to the next selected text.

The structure and chunking of the text is more important on a VDU than with paper. The text and layout need to be designed for the medium. Plentiful use of organizing headings and concise prose should ensure

that each screen page can contain one main chunk of information that has reduced dependency on other screen pages for its understanding. This reduces the memory burden on the reader between pages and increases comprehension.

Each screen page should be uniquely identified and should indicate to the reader the action required to change pages. This information should be given in consistent screen locations (e.g. top and bottom lines) and should be visually distinct from the text, for instance by colour coding. Menus are recommended for interactive text where the reader has to select from a number of options. Design each screen to give an uncluttered display which makes full use of the screen and is balanced horizontally and vertically.

7.3 Visual Enhancement

Screens offer facilities not available on paper that can be used for structuring and organizing the text, such as colour, reverse video and flashing, though these can distract attention from the meaning of the text if overused.

* Flashing should be used for vital warnings only. Your intention must definitely be to interrupt normal reading.

* Reverse video also captures attention and draws it away from other areas so it should be used sparingly, for instance, for routing information.

* Brightness variation of text characters is not generally advised, though two intensities are acceptable to show bold and ordinary text.

* Text colour is a useful cue or way to structure the text, but do not use more than three text colours per screen, and keep consistency of colour meanings between screens. Background colour should be used sparingly. Use colour-on-colour combinations that have a high text-to-ground brightness contrast.

Lists of options or points of information should be differentiated from the text by layout or typographical cues, such as indentation, bullets and blank lines. Do not fill lines out artificially.

7.4 Controlling Text Viewed

When the portion of text is larger than that which fits on the screen at one time, it is necessary to have some form of scrolling or windowing function that allows the user to control the movement backwards and forwards within the text. It is important that the user feels in complete control of the scrolling action. Avoid such things as rapid scrolling where the user has to respond quickly to catch the required section of text.

One way of conceptualising scrolling is to visualise the text as if it moves or "scrolls" behind the stationary screen. A scroll down would reveal information beyond the upper limit of the screen. Alternatively, one can visualise the display screen as a movable window through which

the stationary text is viewed. In this case, to display text beyond the upper limit of the screen one would use a "window up" command or up arrow key.

Treating the screen as a window is the most natural for users, and produces fewer selection errors. The same principle should be applied if there is a need to move left or right over the text.

7.5 Warnings and Error Messages

Message quality is a critical factor in influencing user acceptance of a program product. Good error messages can reduce the time and cost to create and maintain software, as well as help users learn about the product. The wording of messages can affect user performance and attitudes towards the system. Whether the source of the error or warning is user input or arising from the computer (i.e. unacceptable data from transducers), the first rule of good message design is to be sure that additional confusion is not created as a result of the message.

A common problem with error messages is that they tell the user what error has occurred, but not what to do about it. Messages are also often written from the point of view of the system's internal workings, and not from the user's viewpoint. Some error messages contain unnecessary jargon, are cryptic, unfriendly, or misleading. For example:

```
IEC141IM 031-4,DESOLVER,BRIDGE,
SHARE1, INPUT(,100A,1,PROJECTA.DATA)
```

Messages need to be brief but informative, telling the user what error or condition has been detected and what action to take. The message should be appropriate to the user's level of knowledge, place no fault on the user, not use patronising language, and not be humourous. Diagnostic messages should be specific, offering constructive guidance, with user-centred phrasing, in a suitable physical format, and avoiding vague terminology.

The goal of providing the message should be identified. To be meaningful, the message should not just be readable, they should be relevant, specific, timely and helpful.

8. ABBREVIATIONS

8.1 Introduction

This section describes ways to construct good abbreviations for use with computer systems. They serve two purposes. One is to speed data or command entry. By encoding messages, that is, by translating words into abbreviations, the amount of time spent in keyboard entry can be reduced. Conversely, abbreviations may be used to reduce the space needed to display messages, options or captions to data. This requires the user to decode, that is, translate the abbreviations back into words.

8.2 Construction of Abbreviations

The most frequently used abbreviations are ones that are produced without recourse to a rule. Usually, system designers rely on intuition to create abbreviations. But there is little consistency in how people choose to abbreviate a word: even if users are asked to construct natural abbreviations, the most popular choice is usually less than a majority, so "naturally" produced abbreviations are very largely idiosyncratic. Internal consistency (i.e. a rule-governed structure) is more important than simulated naturalness, so use a rule for constructing abbreviations, rather than what seems natural.

Construct abbreviations by truncating.

The most effective way for constructing abbreviations is to retain just the first few letters of the key word. Other rules, such as vowel deletion, are less effective. This is probably because it is obvious in every case how to apply the rule, once the user knows it. Even if the user is not explicitly taught the rule, but learns it through repeated use of the system, a truncation rule is more quickly learnt. An abbreviation rule brings advantages in terms of learning, errors and naturalness to the largest number of users. The abbreviation should not include any punctuation.

The length of the truncated abbreviation should be the minimum to achieve uniqueness of the keyword (see the subsection on uniqueness below) and should be the same for all abbreviations. If the length varies, users may type in more than necessary to be sure of uniquely defining the keyword, thus losing some of the advantage of abbreviation.

8.3 Stereotypes

In some cases, there may already exist a set of abbreviations which are well-known to the user population. In these cases, the existing abbreviations can be used in preference to constructing a new set to be learnt, because the memory of the learnt set would interfere with the learning and error-free use of the new set.

8.4 Uniqueness

Occasionally, truncation to a fixed number of letters produces non-unique abbreviations. If there are only a few words whose abbreviations cannot be be unambiguously defined, it is acceptable to create abbreviations that violate the truncation rule. As long as there are very few of these exceptions, preferably used with infrequently used keywords, then there may even be an improved memory of them because of their uniqueness.

8.5 Multi-Word Terms

If an operation or label cannot be described in one word, then a different rule for abbreviating the phrase should be used: retain the first letter of each word, for instance, Radio Frequency - RF, or GP for Graphic Print. A multiple word command line can have the truncation rule applied to separate options within it, e.g. "PRI SAL FOR A to Z " stands for "PRINT SALARY FOR [employees' names] A TO Z".

A1. INPUT/OUTPUT DEVICES

A1.1 Introduction

Devices that are used for interacting with the computer should be matched to the user's tasks.

Some tasks are best performed with certain types of input or output devices, e.g. keyboards, joysticks, VDUs and printers. To decide which devices a computer system should have, one should first think of the tasks that the user is expected to do. This section describes the devices that are suited to some common tasks. These are:

* Choosing options.
* Positioning a cursor.
* Numeric entry of data.
* Small amounts of text entry.
* Large amounts of text entry.
* Generating a drawing.
* Entering an existing drawing.

A1.2 Device Characteristics

The **mouse** is good for choosing options from menus and positioning an object on screen. It is pushed along a flat surface near the display. It can have integral keys making it a self-contained device for input in some applications.

The directions of its movement should produce a corresponding movement in the same direction on the screen. The necessity for a smooth flat surface and the presence of a trailing cable may be a disadvantage, building a **joystick** into the keyboard removes this problem. A joystick is also effective for choosing and positioning tasks. **Tracker balls** or rolling balls are also effective in this context, though, like joysticks, they can easily be spoilt by poor mechanical design.

The **lightpen** and **touchscreen** both suffer from the fact that the best position for viewing a display is further away than the comfortable position for pointing. Neither can give high resolution and they can be affected by dirt on the screen. They may be suited when a keyboard is undesirable or when the environment is hostile but not dusty.

Soft keys are unmarked keys placed around the display screen whose functions are indicated on the screen. Thus their function can change according to context. Care should be taken to ensure that they do not require the user to keep changing position to reach the screen.

Graphics tablets. Direct graphical input devices improve productivity by reducing the number of transactions the user must perform. Keyboards uually prove less optimal for choosing and positioning tasks, but tablets may not be good unless the drawing surface is immediately in front of the display. The tablet surface must not be gouged easily by putting the pen on it. The surface should be matte or as non-reflective as possible.

Alphanumeric keyboards:

Alphanumeric keyboards should conform to the standard QWERTY arrangement.

Additional function keys on an alphanumeric keyboard should be grouped around this standard arrangement. They should be used judiciously to minimise typing in dialogues and should have clear functional labels (rather than arbitrary ones, such as 'f1').

A repeat function should be built into individual keys, rather than provided with a separate key.

A1.3 Positioning

In order of preference, use a mouse, joystick or tracker ball, light pen or touchscreen, cursor keys.

Positioning means specifying or changing the position of a displayed object, often a cursor. The mouse is quickest in terms of total task execution time, that is, the time taken for the hand to leave the normal keyboard, execute the pointing task and return to the keyboard.

A1.4 Numeric Entry

In order of preference, use a numeric keyboard, alphanumeric keyboard, tablet.

If the user has to enter a large number of numeric data, then a numeric keyboard is better than the standard arrangement of numbers on an alphanumeric keyboard.

A1.5 Text Entry

Use an alphanumeric keyboard.

A standard QWERTY keyboard is always be better than one with a different arrangement of keys unless considerable training is given to all users. Even completely novice users are no quicker or more accurate using another keyboard layout, such as an alphabetical arrangement. A tablet is acceptable for small amounts of text entry.

A1.6 Generating a New Drawing

In order of preference, use a tablet, mouse, lightpen.

A tablet and mouse give more control and resolution than a lightpen. A tablet is better than a mouse because the user can see the exact position of the stylus on the tablet.

A1.7 Entering an Existing Drawing

Use a graphics tablet.

This is sometimes known as digitising. A tablet is better than other devices because it allows the user to trace the exact outline of an

existing drawing with a stylus.

B1. BAR CHARTS FOR MONITORING AND CONTROL

B1.1 Introduction

Bar charts are effective in some industrial supervision and monitoring tasks to represent the status of several variables on one screen. They may be easier for some operators to use because of their similarity to traditional analogue instruments.

B1.2 Monitoring for Deviations

With many variables represented on one screen it is appropriate to have some form of group scaling, so long as it is not essential that the operator knows exact values. This can be done with respect to maximum and minimum values (perhaps with a percentage scale), setpoints or high and low alarm limits.

Use some form of coding to indicate alarms, such as colour.

Scanning time and error rate rises with the number of variables displayed. A dozen or so variables can be scanned in a few seconds but double this time is needed for sixty variables. Even for a few variables (e.g. 12) a significant number of detection of deviation errors are made. Hence, if detection of deviations is essential to the user's task, some form of back-up coding is needed, such as colour coding, or even an alarm message.

Use a stroke-type display in preference to bars.

A stroke format allows the eye easily to look along the states of each variable and detect those outside displayed bounds.

Put strokes in a row, as opposed to a column.

The bar format is worse in terms of both search times and errors, but has the advantage that it is easier to look along a bar to find the name of a variable that is deviating. With strokes it may be better to show the outline of a bar faintly leading down to the axis from each stroke, so that the user can more easily find the name of the variable.

B1.3 Check-Reading

Analogue representation is better in terms of speed than a numeric one because numbers involve mental subtraction. Users also prefer it.

Scale markings to high accuracy on each variable (e.g. 5%) actually interfere with this type of task compared with coarser markings (e.g. to an accuracy of 20-25%.) For a checking and comparing readings (e.g. picking the variable with the highest measured value) it is better in terms of speed to orient the bars or strokes vertically and to use some form of supplementary colour-coding to allow the eye to avoid information irrelevant to this particular task. Again users prefer these.

Generally, a layout which uses both rows and columns for positioning the bars is superior to a one-dimensional layout (e.g. where the bars are all in a row or a column) because this allows an experienced user to adopt a strategy of knowing where a particular bar is and looking to it directly.

C1. TEXT

C1.1 Introduction

This appendix gives guidance on writing and laying out ordinary text, primarily for presentation of user documentation, whether printed or on screen. Issues specific to the presentation of text on VDUs are given under a separate heading in the main body of the report.

A writer should develop a clear conception of the audience for which the text is intended, their past experience and expectations. This gives insight on what information to include, and how to structure the text. It avoids placing excessive demands on the reader. Words are clearer in meaning than pictures and are essential in the representation of abstract concepts.

C1.2 Titles

Use a title as a succinct expression of the contents of the text.

It should contain the fewest words possible, and works better if it is highly memorable. It helps focus attention and expectations.

C1.3 Summaries

Use summaries before and after the text.

Summaries before the text inform the users about the content - so they can decide whether to read it and find out what the text is about. Summaries after the text help recall and understanding of the text by presenting the main points and conclusions.

C1.4 Headings

Use headings in the text to help comprehension, scanning and searching.

Headings label parts of the text so that users know where they are and where they are going. They help with scanning, selection and retrieval as well as comprehension.

Try to anticipate how readers will look for information, if they are likely to treat the text as a reference. Will they want to access information alphabetically, chronologically, procedurally or by categories? Tell, or show, the reader what the arrangement is.

Headings can be placed in the margin or with the text. Headings in the margin may help more with scanning and searching. If headings are written in the form of questions they may help the understanding of a young or less able reader (if the text answers the question) but

headings in statement form are always acceptable.

Provide at least two or three meaningful headings per A4 page or its equivalent, and try to reflect the user's tasks and structure of the document in their wording. Bear in mind how the Contents page will look when choosing the wordings: some headings which make sense in the text may not make sense when presented out of context in the Contents pages.

C1.5 Advance Organizers

Use these to help give a conceptual structure to the text.

Advance organizers indicate ways in which new material is the same as, or different from, what the user has already read. They give material immediately before a text passage that is introductory, more general and more abstract than the following text. They perform a similar function to headings, but they may contain more text (usually 10 to 15% of the text passage) and they can be shown in a different way typographically, for instance, by using a large margin devoted solely to advance organizers. They provide a conceptual framework that helps clarify the task ahead, and improve the memory and attitudes of the reader.

Advance organizers are written to:

* Provide an advance 'scaffolding' to hold up new ideas as they are given in the text.

* Mark the introduction of new ideas or concepts.

* Bridge the gap between what is known and what is to be learnt.

Good organizers are:

* concrete models
* analogies
* examples
* sets of higher order rules
* discussions of main themes in general terms

Organizers should not be used for:

* factual presentations
* summaries
* outlines
* directions to attend to specific portions of text

C1.6 Paragraphs

The theme of each paragraph or section should be stated clearly at the beginning in order to focus the reader's attention on the main point being developed. The overall organization of paragraphs within longer stretches of text should reflect judgements about the relative importance of ideas being presented. Major concepts should not be buried in a mass of detail.

C1.7 Sequencing

If the events reported in the text have a time sequence then the sequence should match the order in which events occur. This is particularly obvious in the case of written instructions, where the reader performs an action to match each instruction. Compare "Remove cover-plates only after isolating the machine" with "Isolate the machine before removing cover-plates."

Users prefer text that has lists and sequences of instructions separated and spaced out, rather than given in running text. Compare "The main uses of colour in graphic displays are:

* for aesthetic and commercial appeal;
* as a supplementary form of coding;
* as the only form of coding".

with "The main uses of colour in graphic displays are for aesthetic and commercial appeal, as a supplementary form of coding and as the only form of coding."

C1.8 Numbering Systems

Use numbers mainly for reference.

Sequencing can be aided by the use of numbering systems. There are many different ways, e.g. 1, 2, 3 or 1.1, 1.2, 1.3, etc. They are especially valuable for reference purposes. Page numbers and chapters are adequate for ordinary running prose.

C1.9 Footnotes

Avoid using footnotes in plain text.

As well as being a nuisance to type and print, footnotes are an irresistible interruption to the reader. They break concentration and the flow of information from one sentence to the next. Excess material can be placed in an Appendix - though it may not then be read.

C1.10 Words and Sentences

Use short, familiar words rather than technical terms that mean the same thing.

Use short sentences. Split up long sentences.

Try to use words you think your reader will understand. Avoid synonyms for the sake of elegant variation, they may well confuse your reader. By the same token, use one meaning per term and do not introduce unnecessary new terms.

Long sentences are more difficult to understand, partly because of the extra memory load they place on the reader. They contain a number of subordinate pieces, such as used here, which, because of their parenthetical nature, make it difficult for the reader to bear all of

their points in mind and, as a result, make it more difficult for readers to remember the first part of the sentence when they are reading the last part. (See what we mean).

There is a distinction between 'given and 'new' information in the course of reading text. 'Given' information has already been mentioned in a preceding portion of the text, while other ideas in a sentence are new since they are being introduced without prior mention. Generally, the subject of the sentence (usually the first thing mentioned) should reflect given information. When it does, it serves the function of tying the ideas in a passage across sentence boundaries. For example, "Shearers can now be steered under computer control. One such system is called 'MIDAS' ".

As a rule of thumb, sentences less than 20 words long are usually fine. Sentences 20 to 30 words long are probably satisfactory, 30 to 40 words is suspect and sentences containing over 40 words benefit from rewriting.

Few sentences should contain more than two subordinate clauses.

Subordinate clauses are modifying statements tagged on to the main sentence. The more there are, the more difficult it is to understand the sentence. For example, "The consequences of ever increasing levels of automation and computerisation, from both the system ergonomic and the socio-psychological part, have shown that, according to current patterns, conditions tend to be rather worse for man".

Active sentences are generally easier to understand than passive ones.

Use positive terms, rather than negative ones.

Usually it is best to avoid negatives, especially double or treble ones, e.g. "It is not unlikely that this document will not be used by non-NCB staff". Exceptionally, if the reader is likely to make an assumption, then you may sometimes use a negative construction to deny it.

As a general rule, a simple affirmative sentence is easiest to understand. Introducing the passive form or negatives creates problems, either slowing the reader down or causing errors. It may also cause memory faults: a sentence in the negative or passive form may be remembered in the active form, even though this may change the meaning.

Try to anticipate the way the reader's mind works:

* General to specific.
* Simple to complex.
* Known to unknown.
* Cause to effect.
* Problem to solution.

When other people read what you write, do not make excuses if they cannot easily understand it.

C1.11 Ambiguities

Many sentences can turn out to be ambiguous, often because the writer's implicit understanding has not been conveyed to the reader, thus allowing an interpretation that the writer had been prevented from seeing because of implicit extra knowledge. This may be more important for instructional or procedural text. It helps to test the material on the target audience to trap this sort of error.

Ambiguities and difficulties can arise from the use of abbreviations and acronyms. Their meaning should be explained to the reader, at least on their first occurrence.

C1.12 Difficulty

There are many readability formulae that quantify and predict the difficulty of reading text. These generally give an American reading grade level (1 - 12) or an index from 0 to 100. Often there are inconsistencies between different formulae on the same text, but one that has had limited validation on technical material is called the Automated Readability Index. This version of the formula gives scores from 0 (easy) to approximately 100 (hard):

$$ARI = (w/s) + 9(l/w)$$

where:

ARI = Automated Readability Index
w/s = words per sentence
l/w = letters per word

This formula should not be used on text much shorter than 10 pages, 5 at the very minimum - otherwise the reliability of the index falls unacceptably.

Such formulae are obviously not an infallible guide to the readability of text; some short sentences are difficult to understand and some long words are easy to read because of their familiarity. Nonetheless, there have been shown to be advantages for more readable text for several types of document, including textbooks, scientific papers and job aids.

C1.13 Alternatives to Prose

Some types of document are difficult to understand when presented in pure running text form. Flow charts, sentences written in the form of linked statements, and even decision tables may be more appropriate to certain material. The optimal format depends upon the topic and conditions of use.

APPENDIX B: MIDAS JOB DESCRIPTION QUESTIONNAIRE

This appendix shows the job description questionnaire which was produced to provide the basis for the structured interviews of MIDAS users. It also includes an introductory preamble which was produced to provide those conducting the interviews with background information and instructions on the use of the questionnaire.

MIDAS JOB DESCRIPTION QUESTIONNAIRE

INTRODUCTION

The large number of data items available to the MIDAS Surface Software (MSS) system means that the resultant information is potentially useful to a wide range of users. In order to meet the needs of as wide a range of users as possible and also to ensure that all of the information is available the software has been written to allow the maximum amount of flexibility. For example, it will allow the plotting of line graphs, scatter graphs and pie charts etc. for almost any combinations of the available data.

Although this approach ensures that all the possible combinations of data are available to the users, it also has the effect of increasing the the amount of interaction that is required and hence the opportunities for the user to make mistakes. It also makes it very likely that the situation will arise where the information required by a single user is spread across many displays and in differing formats.

From the user's point of view however, a good system is one that contains all the information required for a single task on a minimum number of screens and in a format that most closely suits the way the data are used. To achieve this objective, it is necessary to consider in detail the tasks the user is expected to perform in conjuntion with the system.

In order to obtain a detailed description of the tasks, the user is expected to perform with the aid of the system the following questionnaire has been developed.

In addition to providing a detailed task description, the questionnaire will also provide information on the frequency of task performance, the possible benefits to be gained by improving task performance and the possible consequences of poor task performance.

This questionnaire is to be filled in by an ergonomist who will use it as a framework to conduct a structured interview.

It is proposed to interview:

(a) The project and software design personnel

(b) The installation and commissioning teams.

(c) Area and pit based personnel who:

- (i) currently use or have access to MSS data;
- (ii) are soon to have MSS installed;
- (iii) have enquired about potential further uses.

GUIDE FOR APPLICATION OF QUESTIONNAIRE

For any individual being interviewed it is intended to complete a questionnaire set for each surface 'job' that he may do which uses or could use information from MIDAS sensors. In the case of non-colliery personnel (e.g. software design or commissioning team) this relates to jobs which they feel could or should be done using MSS.

The job of a CRO may be to pass the information on to a third party, while the manager may be compiling a report on the viability of the face etc..

The first page of the questionnaire deals with personal details of the 'subject' together with an indication of their use of the MSS system.

Page two requires a listing of each of the jobs which the subject carries out (or is aware of as a potential job) which come under the description above. This list should be referred to subsequently to ensure that all jobs are covered. In the case of programmers or commissioning team members, please ask them to indicate who would be expected to do the job described.

The next page is the first detailed page. It requires a description of the job, working through all the stages associated with the acquisition and use of MSS information. It has been presented as an unstructured sheet to allow as much flexibility as possible. The interviewer should complete this in note form during the interview, rewriting it if necessary for clarity as soon as possible after the interview. During this stage of the interview, the interviewer should 'flag' in his notes each information item as it arises, numbering them for reference.

After the job description is completed the interviewer should complete an information description sheet, numbering each item for cross reference with the job description text.

After completing this for each information item the interviewer should obtain ratings of the job on a job assessment profile form before moving to the next job.

Finally, the interviewer should ask the subject to complete a MSS System Rating Form.

On the first visit to each pit please complete a MIDAS installation information sheet.

MIDAS JOB DESCRIPTION QUESTIONNAIRE

Questionnaire Number .... Date. ....

Ergonomists Name. .... Location of interview. ....

SUBJECT DETAILS

Subject Name. .... Subject Number. ....

JOB TITLE or brief description where job title is not self descriptive

....

....

....

Normal place of work, phone number and extension on which subject may

normally be contacted.....................................

Duration of relevant experience....................................
(N.B. This may be different from time with Board or time in job.
The interest is in experience relevant to current job.)

Level of involvement with MSS.	Software Development	[ ]
	Commissioning/National	[ ]
	Area	[ ]
	Pit	[ ]

Any experience with other computer systems.	Yes	[ ]
(either at work or at home)	No	[ ]

Other types of systems used. ....

MIDAS JOB DESCRIPTION QUESTIONNAIRE

MIDAS ASSOCIATED JOBS

Subject Number ....

Please list each of the jobs which you do or which could be done using information from the MSS system. This may be something which MSS information is currently used for or it may be some job which you are aware of which could make use of MSS information. The "job" is therefore the use or potential use of information from the MSS system, rather than the specific act of obtaining that information. Thus the job of a CRO may be to pass the information on to a third party, while the manager may be compiling a report on the viability of the face etc.. At this stage, we just want a list of the jobs. We will then fill in the detail later.

MIDAS ASSOCIATED JOBS

1)...

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2)...

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3)...

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4)...

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5)...

....

MIDAS JOB DESCRIPTION QUESTIONNAIRE

MIDAS ASSOCIATED JOB DESCRIPTIONS

Subject Number ....

Job Number [....] Page 1

MIDAS ASSOCIATED JOB DESCRIPTION

Job classification. Current....... Potential....... Desirable.......

How often is (or would) this job be carried out.

Every day [ ]
Weekly [ ]
Monthly [ ]
Annually [ ]
Other [ ]

Please specify e.g. occasional job at irregular intervals.

....

Please describe the tasks which have to be carried out in order to do this job detailing all individual items of information which have to be obtained. Care should be taken to ensure that these are single items not clusters of information such as several aspects from one feature (e.g. machine speed, machine speed over last shift etc.). Information items should be labelled and an information requirements sheet completed for each one. Please indicate if any of these information requirements depend upon the value/status etc. of previous information.

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MIDAS JOB DESCRIPTION QUESTIONNAIRE

MIDAS ASSOCIATED JOB DESCRIPTIONS

Subject Number ....

Job Number [....] Page [.....]

MIDAS ASSOCIATED JOB DESCRIPTION, CONTINUATION SHEET

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MIDAS JOB DESCRIPTION QUESTIONNAIRE

DESCRIPTIONS OF INFORMATION REQUIREMENTS

Subject Number ....

Job Number [....]

Item Number [....]

If it becomes apparent that more than one item has been included here then please number as N.1,N.2 etc. and complete separate sheets for each item.

Description ....

....

Checklist on type or nature of information

Please indicate the descriptor which best describes this item of information

Status i.e. on/off	[ ]
Level vis-a-vis a limit	[ ]
Trend data	[ ]
Change in comparison to previous value	[ ]
Actual numerical value	[ ]
Other (please specify)	[ ]

....

Where is this information from?

MSS Screen [.....] Parameter name [......]

Other (please specify)..

....

If MSS is used please give the most frequent method adopted for obtaining this information from the MSS system.

Getting it yourself	[ ]
Others get it for you	[ ]
Routine Printout	[ ]
None	[ ]

If this information is obtained for you by another individual please give details where he may be contacted

....

MIDAS JOB DESCRIPTION QUESTIONNAIRE

DESCRIPTIONS OF INFORMATION REQUIREMENTS SHEET 2

To what accuracy is this information normally given....................

....

How accurate is it actually required to be.............................

....

How reliable do you consider it to be..................................

....

Does it need to be more reliable..............................YES / NO

If NO, could this job be done with less reliable information. YES / NO

Is this information provided in a directly useable form ....YES / NO

If NO what additional calculations have to be performed.

....

....

MIDAS JOB DESCRIPTION QUESTIONNAIRE

Subject Number ....

ASSESSMENT PROFILE RECORD SHEET

Please rank the extent to which the following aspects of mining would be affected by changes in system performance factors such as accuracy or speed of information production for each job.

	JOB NUMBER							
	1.	2.	3.	4.	5.	6.	7.	8.
SAFETY	..	..	..	..	..	..	..	..
PRODUCTION	..	..	..	..	..	..	..	..
INDUSTRIAL RELATIONS	..	..	..	..	..	..	..	..
MAINTENANCE	..	..	..	..	..	..	..	..
LONG TERM PLANNING	..	..	..	..	..	..	..	..
OTHERS (Please specify)	..	..	..	..	..	..	..	..

Please give details of any 'others', together with any information which you may consider relevant as to why you have given any particular rating

....

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MIDAS JOB DESCRIPTION QUESTIONNAIRE

RATING OF USEFULNESS OF CURRENT MSS SYSTEM

Subject Number ....

Job Number [....]

Please rate the Midas Surface Software not the whole Midas system by making a mark on the rating lines from 1-7 as shown.

1.....2.....3.....4.....5.....6.....7

How useful would you consider the current MSS system to be as an aid to:-

1. Production

   Not at all 1.....2.....3.....4.....5.....6.....7 Tremendous help

2. Safety

   Not at all 1.....2.....3.....4.....5.....6.....7 Tremendous help

3. Long term planning

   Not at all 1.....2.....3.....4.....5.....6.....7 Tremendous help

4. Industrial relations (bonuses etc.)

   Not at all 1.....2.....3.....4.....5.....6.....7 Tremendous help

5. Maintenance

   Not at all 1.....2.....3.....4.....5.....6.....7 Tremendous help

Comments.
....
....
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MIDAS JOB DESCRIPTION QUESTIONNAIRE

ASSESSMENT PROFILE RATING SCALE

This scale should be used in conjunction with the Assessment Profile Record Sheet.

Greatly Impaired	A.
Slightly Impaired	B.
No Effect	C.
Slightly Improved	D.
Greatly Improved	E.

MIDAS INSTALLATION INFORMATION SHEET

How long has a MIDAS or similar installation been in your pit.........

Has the software (MSS) been available all this time YES / NO

If not, for how long has it been available...........................

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